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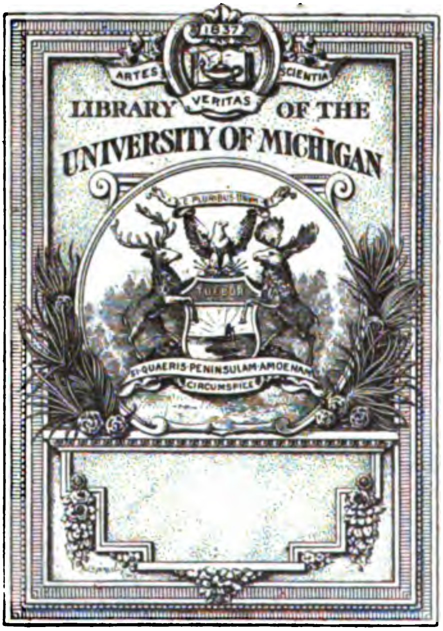
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THE EVOLUTION OF LIFE

CAUSES OF CHANGE IN ANIMAL FORM

A STUDY IN BIOLOGY

BY

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G. P. PUTNAM'S SONS
NEW YORK [illegible] LONDON
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The Knickerbocker Press
1891

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OR

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A STUDY IN BIOLOGY

BY

HUBBARD WINSLOW MITCHELL, M.D.

G. P. PUTNAM'S SONS
NEW YORK LONDON
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The Knickerbocker Press
1891

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BY
HUBBARD WINSLOW MITCHELL

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G. P. Putnam's Sons

TO MY WIFE

SARA MAKEPEACE MITCHELL

WHO FOR TWENTY-FIVE YEARS HAS BEEN MY DEVOTED
COMPANION AND FAITHFUL FRIEND, THIS BOOK
IS AFFECTIONATELY DEDICATED

PREFACE.

THE great question of "The Evolution of Life" upon the earth, and the causes that have led to the successive changes in animal forms, is one that should be treated from an anatomical and a physiological point of view. Scientists have hitherto spoken of these changes that have taken place, and have concurred in the opinion that the lower forms of life have advanced in the scale of development, and in time have given rise to higher and newer forms. It is believed and generally accepted that the protoplasmic cell was the first vital organism that appeared upon the earth—that, following this in order came the protozoans, the fishes, the reptiles, the marsupials, the mammals, the higher apes, and finally man, but no attempt has ever been made, as far as I know, to explain the physiological causes of these changes in the anatomy of the animal kingdom. It is only a part of the truth to say that a reptile was evolved from a fish, a mammal from a reptile, and man from the higher apes. But this is not enough. The world is advancing to that point when it demands to know *how* these changes took place, by what physiological process they occurred, and what was the reason that induced them to change. It is this great point that I have endeavored to explain,—how far, and how well I have succeeded, I leave others to judge. If anything is left unsaid or unexplained it may serve as a stimulus to future writers to finish the work I have planned out. I have written this work from a physiological standpoint, and in the train of thought naturally held by a medical man. The views upon the geological changes of the earth are those held by modern geologists. The ideas I have advanced concerning the Arctic Archipelago, the bridge of land at Behring Strait, the bridge of land along what is now known as the Windward Islands, and the connection of Australia with the main continent of Asia, and the formation of the Straits of Magellan, are reasoned out by the aid of geological data, and appear to rest upon scientific facts, as far as I have been able to observe them, in those localities.

It was my good fortune to travel extensively during many years, and to visit different and distant parts of the world, where men rarely had an opportunity to go, and during these years of travel, made under the most pleasant and favorable auspices, I was able to observe phenomena and study past changes in geological history, and to collect many facts which I have endeavored to embody in this book. The views here stated upon the origin of life, and upon that peculiar principle called chemical force, are reasoned out as a matter of necessity in conformity to known laws, and it seems to me difficult to arrive at any other conclusions than those here reached. These conclusions have been arrived at from necessity, as a mathematical answer must be correctly reached when the example is worked out on correct principles. I have not encumbered the pages of the book with footnotes, or numbers, nor with references, but the ideas here set forth are substantiated by the writings of such men as Cuvier, Kant, Lamarck, Laplace, Haeckel, Darwin, Wallace, Agassiz, Huxley, Marsh, Dalton, Draper, Leidy, Prudden, and others, whose names have been made illustrious by their able scientific works. These names have shed a permanent and glorious lustre upon the scientific world. I have consulted them freely, and desire here to give them full credit for all they have done and all they have taught. I am aware that it would be impossible in a single book to cover so vast a field. It would require many volumes to treat properly of so great a subject as this, beginning with the earliest condition of gaseous matter in the universe, and tracing it through all its successive and manifold changes, not only to our own time, but onward in the future, until changes occur to once more reduce it to incandescent gas.

I have not been able to treat fully this magnificent and fascinating subject, for in a busy life like mine, only the more important facts can be given. It would require years of labor to properly set forth the many interesting facts and truths in anything like an adequate form. If my work stimulates research into a region hitherto only partly explored, I have accomplished all that can be reasonably expected from a medical man deeply immersed in the duties of his profession.

August 1st, 1891.

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THE EVOLUTION OF LIFE.

CHAPTER I.

COSMOGONY.

The study of the earth—Facts learned by reasoning backward—Nebular hypothesis—Kant and Laplace; their theories—The incandescent state of our earth—It was thrown off from the sun—A great central mass of fiery vapor—The action of chemical force; it causes an explosion—Other suns are formed—Composition of the sun and stars—The spectrum of the stars—Elements of the stars—Fixed stars—Nebulæ—Sidereal system—Motions of the stars; their distances—Parallax of stars—Space; its qualities—Loss of heat in space; its future consequences—Other worlds than ours—Our planetary system.

THE study of the many structural changes in the forms of animal life that have successively appeared upon the earth during past geological ages requires a knowledge of some of the more important changes that have taken place in the earth itself.

We must know something of the past history of the earth, and of the geological changes it has undergone, in order to clearly understand what vital processes have taken place upon it.

We shall learn that the slow evolution of animal life has progressed simultaneously with the slow evolution of plant life, and that both have kept pace with the slow and orderly development of the earth.

That the earth itself has undergone a process of development, slow and sequential in its character, from a primitive condition when life was impossible upon it, is a well-known geological fact.

By a process of reasoning backward, we can trace by regular and successive steps the changes that have occurred in the earth's crust, the outlines of sea-coasts, the areas of continents, and the elevations of mountain chains. We can see that the dry land diminished in extent, that coast lines grew fainter, and that oceans were more extensive until they were universal. Still tracing our backward course, we can see that the ocean grew less salt until it became fresh, and then gradually hot and hotter still until it only existed as vapor. That the earth gradually increased in temperature until it existed as a molten mass and finally as incandescent vapor. At this point we stand where the

NEBULAR HYPOTHESIS

seeks to account for the origin of our earth and the planetary system of which we form a part.

Kant and Laplace advanced the theory that in remote times our earth existed as a gigantic mass of glowing vapor or gas; that this mass of incandescent vapor was thrown off from a larger central mass, which in cooling and contracting gradually attained a rotary motion, and finally became one of a system of planets circling around the still glowing central mass or sun as we see it to-day.

Kant's theory maintained that "the whole universe consisted of a gaseous chaos. All the substances which now are found on the earth, and other bodies of the universe in different conditions of density, originally constituted together one single homogeneous mass equally filling up the space of the universe, which, in consequence of an extremely high degree of temperature, was in an exceedingly thin gaseous or nebulous state.

"The millions of bodies in the universe which at present form the different solar systems did not then exist. They originated only in consequence of a universal rotary movement, or rotation, during which a number of masses acquired greater density than the remaining gaseous mass, and then acted upon the latter as central points of attraction. Thus arose a separation of the primary gaseous universe into a number of rotating nebulous spheres, which became more and more condensed. Our solar system was such a gigantic gaseous ball, all the particles of which revolved around a common central point, the solar nucleus. The original gaseous condition of the rotating bodies of the universe gradually changed by cooling and condensation, into the fiery fluid or molten state of aggregation. By the process of condensation heat was emitted, and the rotating planets soon changed into glowing balls of fire which emitted light and heat. By loss of heat the melted mass on the surface of the fiery fluid ball became further condensed, and thus arose a thin firm crust, which enclosed a fiery fluid nucleus."

In all essential respects this nebular theory of Kant harmonizes with all the general series of phenomena at present known to us, and is not specially contradictory of any of them. His idea of the origin of the universe was grand and comprehensive.

But he did not go quite far enough, and our loftiest ideas seek for something more. When we look into the star-lit heavens at night, and see the myriad points of light, we ask what are they, and from where did they come? Our modern telescopes tell us that they are gigantic luminous bodies, and the spectroscope tells us that they are similar, if not identical, in composition to our own sun and our earth. We see that they are aggregated in a certain portion of space, and that some parts of this aggregated mass are more thickly strewn with stars than others, while beyond, and in the remotest depths of space, no stars appear at all. Measurements of stellar parallax tell us that some of these luminous bodies lie at distances so great, that a ray of light would require thousands of years to cross the mighty gap. Yet even these, far distant as they are, yield their ray to the spectroscope, and we see that they in no wise differ from our own sun. Great as the distances may be between the remotest stars on the confines of what we may call this *stellar aggregation*, it is an *aggregation* still, and all the stars and nebulous points of light belong to it. In other words, all the stars, nebulæ, comets, and luminous points of light, visible to us by the aid of our greatest telescopes, belong to *our universe*. We have no reason for believing that any stars exist beyond it.

Whence came all these suns, for such we believe them to be?

It is quite reasonable and purely logical to believe that in a remote past age all these distant and widely scattered bodies constituted *one single vast body* of glowing, incandescent vapor. Immense as this body of burning vapor must have been, gigantic as was its vast dimensions, the human mind can easily appreciate it, if we will remember the boundless depths of space. Such an enormous mass of fiery vapor must have given rise to the most tremendous *chemical activities*, and these chemical activities must have developed an *energy* which caused an explosion and which rent the great mass into millions of fragments.

Such an explosion could have easily occurred, in such a vast, fiery, seething mass, by the generation of *chemical force*. This *chemical activity*, or *chemical force*, generated in the mass itself by the great heat and friction of its elementary components, was sufficiently powerful to burst the huge mass asunder and send its fragments flying off into space. The fragments were of a size sufficiently vast to form single suns, or double suns, or groups of suns, and in some instances they were so attenuated as to form nebulæ, or luminous cloudy masses, or comets, or star dust, so-called. In this way meteors, and meteoric showers, and meteoric dust can be accounted for, simple particles from some of the fragments that have cooled in space.

That these masses or fragments scattered so widely in space are identical in character and chemical composition, is proved by the spectroscope. It is an established fact that when pure white light is passed through a glass prism, it is broken up into its component colors, and these colors arrange themselves always in the same way, namely: violet, indigo, blue, green, yellow, orange, red. These seven colors constitute the *continuous spectrum* of white light. If the light of a burning gas containing any volatilized substance be passed through a prism, the spectrum will not be *continuous*, but is ornamented by bright-colored lines. The metal sodium gives two yellow lines, strontium a red line, silver two beautiful green lines. Iron, zinc, magnesium, hydrogen, and nitrogen all have a definite series of lines which may be readily recognized as its test.

The solar spectrum is not continuous, but is crossed by a large number of dark lines, called Fraunhofer's lines, in honor of their discoverer. It is believed, therefore, that the sunbeam is the light of an intensely heated body shining through a flame full of volatilized substances, for these lines are so distinctive, so marked and varied, that the very elements of which the sun is composed may be discovered. The burning vapor of metallic iron gives seventy bright lines in its spectrum, but these lines are dark when the burning vapor passes through white light. There is no doubt, therefore, that the sun's atmosphere contains iron. Besides iron, the following substances are now known to exist in the sun, for each gives its constant and characteristic lines in the spectrum :

Sodium,
Strontium,
Iron,
Cadmium,
Barium,
Zinc,
Calcium,
Magnesium,
Hydrogen,
Chromium,
Nickel,
Cobalt.

If we apply the same method of analysis to the fixed stars, we shall see that their spectra are also crossed by dark lines, and these lines are so distinctive and so constant that we can easily detect their constitution notwithstanding the enormous abyss that separates them from us. They are like our own sun, and contain the same familiar elements.

The beautiful fixed star Arcturus is almost identical with our sun.

The magnificent Sirius, that blazes so brilliantly in the sky, and those other superb night jewels, that glitter so brightly in the vault of heaven—Rigel, Vega, Capella, Canopus, Alcyone, Castor and Pollux,—are composed of the same elements, while glorious Aldebaran has almost the same components as our own earth. Nine at least of its elements have been clearly discovered, namely:

Tellurium,
Sodium,
Magnesium,
Hydrogen,
Bismuth,
Mercury,
Iron,
Antimony,
Calcium.

Betelgeuse, "that makes the world in love with night," contains several familiar elements, but as far as we now know has no hydrogen. It is, therefore, a sun without watery vapor.

All of these beautiful stars have been examined, and all exhibit the dark lines characteristic of the elements so well known to us.

In the case of Alpha Centauri, Polaris, and other double stars, their spectra shows the same elementary composition.

Thus we trace, not only in the great blazing stars of the first magnitude but also in those fainter points of light that tremble on the far distant confines of our universe, the same elements that enter into our daily food and drink. Truly nature is the same everywhere, and our earth is but a part of a vast system, one of the many millions of bodies that form our great universe.

The spectra of about sixty nebulæ have been examined, and of these, twenty show *bright* lines. We thus have proof that these remote clouds of hazy light are immense masses of glowing gas or vapor, containing many known elements, among which is nitrogen, and in one nebula at least, that in the constellation Draco, hydrogen gave a faint but characteristic line.

Some of the nebulæ have been found to be only hazy clouds of luminous vapor, containing no stars at all, while others have revealed stars and starry points of light, and others again have been resolved into stars by the great powers of our modern telescopes.

If all the stars composing our great sidereal system were originally *one vast mass*, as it is reasonable to believe, and were scattered in space by a mighty chemical explosion, are they now at rest, or do they still move in obedience to the power that first gave them motion? Astronomers tell us that stars are moving in space, and some of them with almost incredible velocity. This is what we should suppose *a priori*. These fragments of the primal mass—these stars that received their motor impulse at the time of explosion, would of necessity continue their flight in limitless and *frictionless* space. Having once received the impulse of motion, the motion would continue indefinitely, because there would be nothing to check the motion. As space is, we think, infinite, these bodies could go on infinitely, and as the impulse of force that each fragment or star received was nearly equal, except perhaps some few that were nearer the centre of the explosive force, the rate of flight would be nearly equal also, and while all the stars are in rapid motion, these motions are nearly in the same direction, and hence the stars show only a slight change of place towards each other. Sirius has been estimated to be receding from us at the rate of twenty miles per second, while other stars are approaching us at the rate of fifty miles per second.

Arcturus is nearing us at the rapid pace of about five miles per second, while Alpha Lyræ and Alpha Cygni are approaching at the rate of fifty and forty miles per second respectively. But so immensely remote are these stars from us that, even at their present high rate of motion, more than a thousand years would be required to show any difference in their brightness. Those stars that are approaching and those that are receding from us are no doubt moving in the same general direction.

Many efforts have been made to estimate the distances from us of the fixed stars, and thus form some idea of the size of the sidereal system. To accomplish this, astronomers have noted the position of a star at a given moment of time, and six months later have again noted its position, when the earth was exactly on the opposite side of its orbit. With this mighty base line for a rule, 183,000,000 of miles in length, only about twelve stars have shown any appreciable change of position. All the rest remain changeless. So that any attempt to prove that the stars have a *proper* motion will be futile, at least at present. The *general* direction of motion would be such as would result from a chemical explosion of the great original mass, *not in every* direction, but in an onward direction like the fragments of a rocket that explodes while in motion. If the members of the sidereal system are moving in a *general direction* through space, as astronomical observations show, to what point are they tending? As space is limitless, it is a sufficient answer to say that they *are* actually in motion, and by virtue of the impulse imparted to them by the original chemical explosive force. There can be no point, nor goal, in a limitless ether. They simply continue on in their flight, because there is no mechanical law to stop them.

The essential qualities of space are *cold* and *darkness.* If it were light and warm the phenomena we now observe in the universe would not only at once cease to exist, but would never have occurred. The light from our sun would not be seen or needed, and his heat would be superfluous. Our earth would forever remain a mass of incandescent vapor just as it was when it was first thrown off from the sun. It could not have cooled and consolidated in *heated space.* It required an intense degree of cold to consolidate such an enormous mass of glowing vapor to its present solidly crusted and permanent condition. Laplace has estimated that the coldness of space would reach 100 degrees below zero of Fahrenheit's scale.

It is a purely scientific fact that heat is dissipated in space, and that it is radiated in every direction from the heated body. What, then, becomes of the heat which emanates not only from our own sun, but from the millions of other suns in our sidereal system?

It passes off into space and, as far as we now know, is forever lost. If heat possesses the property of indestructibility, then it is still somewhere in the regions of infinity. There is no way in which it can return to any sun or heated body, and practically it is lost to us, completely dissipated in the coldness of space.

All the suns in the universe are slowly parting with their heat. It is being gradually dissipated and dispersed. According to this view there must come a time ages hence when all the heat from all the suns will be lost, and the brilliantly luminous bodies we now see in the heavens will become cold and opaque. This is undoubtedly true. Our satellite, the moon, is such an opaque body. It has no heat nor life. It simply circles about our earth a cold mass of naked rock without an atmosphere, scorched by the direct rays of the sun by day and frozen in the coldness of space by night. Our earth and the other members of our planetary system have parted with their heat, with the exception perhaps of Jupiter, and are opaque bodies. Although the earth is so favorably situated as regards its distance from the sun and in its supply of light and heat, yet it is not exempt from the law that deprived the moon of its atmosphere, and will at some future time be a like insensate orb. The sun will, in the flight of the ages, part with all its vast stores of heat and move in space a cold, dark mass of naked rock, and to logically extend this idea, all the suns will follow the same law and radiate their entire store of heat into the wilds of space, when they also will move, dark masses of matter devoid of light and heat.

While these millions of glorious suns that now jewel the vault of heaven are slowly but surely following this natural and inexorable law, while their vast stores of vitalizing heat are silently passing away until they are all gone, yet the process is so slow, notwithstanding the vast scale upon which they evolve their heat, that millions of years must elapse before such an end can be reached, an end that seems to our eyes so melancholy.

And yet not perhaps so melancholy, for doubtless other vital processes will occur in the far-distant future, when the great universe will again become instinct with life, as I shall endeavor to show in the chapter on Terrestrial and Cosmogenic Prognosis.

The nebular theory that we have endeavored to elaborate until it accounts for each body and every mass of matter in our universe, tracing them all backward to a single original mass so vast, so ample in its dimensions, as to be sufficient to form them all, seems not only perfectly logical and scientific, but necessary as a law of evolution of our sidereal system. We have shown in our argument that all these distant bodies are identical in composition to our sun and earth. We know from the labors of scientists that they are luminous suns, vastly exceeding our own in size, that they are, however distant and widely scattered, really members of the great family to which we ourselves belong, that the direction of all is general, and the destiny of all is undoubtedly the same.

This homogeneity of origin, of composition, of order of evolution, of direction, of function, and of destiny, seems so clear and so apparent that it needs no argument to establish it as a purely scientific truth. A little reflection will show that such a view of the nebular theory is a *necessary* view, called for by the regular and orderly evolution of our own earth and of the universe, as scientific observation and investigation have shown us.

The laws of astronomy and of chemistry have revealed to us not only the whole universe, but have taught us that the feeblest glimmer of the faintest star that trembles on the most distant outposts of this vast system of worlds, in no wise differs from this magnificent earth we so joyously and happily inhabit. It has taught us that it is composed of the self-same materials, and was once a part of the same original mass as our planet and all the other celestial bodies in this vast confraternity of worlds. If we could be endowed with the power of infinite flight, and span these great gaps that lie between us and the stars with the same rapidity that our thought passes from us to them; if we could say *here—there*—and compass the mighty distance in that brief interval of time, we could visit those far distant suns, and find them no doubt regulating a scheme of worlds not unlike our own, and perhaps peopled by beings like ourselves, who might be viewing our sun as we view theirs, and with the same wonder. It is not at all unlikely, in fact it is extremely probable, that these great suns may have planetary bodies circling about them, and some of them as favorably situated towards them in regard to a supply of light and heat as our own earth is situated towards our own sun ; and it is entirely reasonable to suppose that planets thus favorably situated may be inhabited by beings not very unlike ourselves, and environed by similar natural scenery, and possessing plants and animals like our own. While this idea can be only purely speculative, yet it is not unreasonable, for there must be in the universe many bodies circling about their central suns, existing under exactly the same conditions that we exist. It is more logical and more scientific to believe that such planets are peopled by beings like ourselves, and contain both animals and plants like ours, than to drift into the realms of the supernatural, and conjure up strange shapes that can exist only in the imagination.

Besides, evolution of animal and plant life must follow the same law there as here. The whole universe is governed by the same law, and the law of the evolution of life must be also the same everywhere. We know that in our own planetary system different conditions must prevail on different planets. If beings live on the planet Mercury, which lies nearer to the sun than our earth, they must be able to endure a greater degree of heat than ourselves, and his animals and plants must be specially adapted to his torrid climate, for when this planet is nearest to the sun in his eccentric orbit, he receives *ten and one half times* more light and heat than we do ; and when he removes to his greatest distance, his supply is still *four and one half times* greater than our own. Venus, who also lies nearer to the sun than ourselves, receives about *twice* as much light and heat as our earth, and therefore, if life exists on that planet, as it probably does, it must be especially adapted to such an increased temperature, and it is not at all impossible that such may be the case. Mars, lying beyond us, outside our orbit, and more distant from the sun than our earth, receives not far from *one third* less light and heat than we, and its favorable situation would make life, such as is familiar to ourselves, extremely probable. The climate of Mars does not differ very materially from our own, and his plants and animals must be similar. The giant planets which lie at such vast distances from the sun, namely, Jupiter, Saturn, Uranus, and Neptune, receive so small an amount of light and heat, that it is not reasonable to believe that any form of life can exist upon them; certainly no form of life that would be familiar to any that we see upon our earth.

There is no need of attributing a different origin to any of the bodies composing our universe. We have shown that spectrum analysis has proved their identity of composition, and it is so extremely probable that it may be called a scientific truth, that every sun and every luminous body or mass, however widely scattered or far distant, is a member of our universal family, and was once a part of a single, original, homogeneous mass. This idea, so reasonable, so logical, and supported by so many demonstrated facts, is beautiful in its sublime simplicity.

CHAPTER II.

THE PALEOZOIC AGE:—THE ARCHEAN OR AZOIC PERIOD. OUR EARTH.

The cooling of the gaseous mass to a semi-fluid state—The formation of a thin crust—The first formation of a thick, murky atmosphere—Formation of water—Mixture of oxygen and hydrogen—Electricity—Cooling of the earth by rain—A universal ocean of hot, muddy water—Relative depths of the ocean—Relative thickness of the earth's crust—The first uplift of land above the universal sea—The Laurentian Hills—The first sunshine on the earth—The earth becomes fitted for the appearance of life.

OUR sun, when it was thrown off from the great central mass, immediately became the centre of a system of planetary bodies, that slowly formed about it during succeeding ages.

It is believed that our sun received a rotary motion from that great central explosive impulse, and that this rotary motion caused it to throw off in turn successive portions of its own substance, which slowly cooled and consolidated in the frigid regions of space through which it passed in its new revolving motion around the sun, until they became planets, having the shape and dimensions we now see. Of course, the outermost planets were detached from the sun first, and long periods probably elapsed between them. Our earth became detached towards the last of these processes of activity. Only two, Mercury and Venus, were formed after our earth.

When the earth was thrown off from the sun, as a vast body of fiery vapor, it received a revolving impulse; and the law of attraction, which thus far has been a fixed law, held it at its present distance from the sun.

As it cooled and contracted in its size, its annual and diurnal motions, as well as its inclination to the plane of its orbit, became fixed and definite; and according to the law of inertia, a body once in motion has no power to stop itself, but will go on forever, unless something occurs to prevent it. Now in *frictionless* space there is nothing to check either of the motions of the earth, and these motions will continue until the sun loses sufficient of his heat to disturb his power of attraction.

This law holds good for all the sidereal bodies and their individual planetary systems.

The primary impulse imparted to all the suns in space will not be disturbed, except as they part with their heat. When this reaches a certain point, all the bodies in space will develop a tendency to fall towards each other in a vast and universal collision.

It will be a subject full of the most absorbing interest to follow the course of our earth, from the time of its first expulsion from the sun, until it became the fitting habitat of animal life.

Let us endeavor to pursue this pleasing study, and follow the interesting steps of the evolution of our earth.

When our earth was a mass of glowing vapor, it was of a size nearly as large as the sun from which it was thrown off, but was greatly attenuated in character.

It was so intensely hot that metals and all solid substances were vaporized; and these, when vaporized, occupy a space about eighteen hundred times larger than when in a solid state.

If, therefore, the earth in its present solid condition has a diameter of eight thousand miles, it had, when in a state of incandescent vapor, a diameter of a little more than fourteen millions of miles.

An ideal sketch of these proportions would convey to the mind a tolerably clear idea of how much the earth has shrunken in volume from its vaporous to its solid condition.

As it circled round the sun in its orbit, the intense coldness of the inter-planetary space exerted a chilling influence upon it, causing a gradual shrinking and contraction. Its intense heat was dissipated slowly, and passed from it into the regions of space.

This process of cooling and shrinking went on during many ages, and the heavier elements sank to the centre of the mass, while the lighter ones, those that were to permanently remain gases, such as free oxygen, hydrogen, and nitrogen, remained on the surface surrounding it. This would happen if we melted to the vaporizing point a number of elements of varying degrees of density, and allowed the mass to slowly cool. The heavier would subside, while the lighter would remain above. The same thing happened in the cooling process of our earth. Hence the solid centre, composed of rocks and metals, and the lighter atmosphere surrounding it, composed of gases and vapors.

As this cooling process went on, the gaseous mass finally reached a time when it became semi-fluid, like molten metal. We must remember that this process, like all processes connected with the geology and evolution of our earth, was extremely slow. It required immense periods of time for its accomplishment.

We can easily imagine that so vast a body so intensely heated, even though it pursued its way through regions of more than arctic cold, must have cooled very gradually.

When it finally reached this semi-fluid form it was probably not far from its present size,—a globe of melted matter pasty in consistence, and surrounded by a thick envelope of gases, intensely heated. These gases were only mechanically mixed; no chemical union had then taken place.

The laws of mechanics tell us that all fluid bodies assume the spherical form when in a state of rotation.

This is a law due to the force of attraction, which acts upon this earth, and probably upon all the other celestial bodies.

It is this law that makes our earth globular in shape. It obeys a simple mechanical law, which forces its fluid elements into a spheroidal form.

Our earth possesses three distinct movements: First, its movement of revolution round the sun, or its annual period of revolution. Secondly, its movement of rotation on its own axis, or its diurnal motion; this causes day and night.

Thirdly, its motion of nutation, or nodding, or its north and south motion. This causes the seasons, spring, summer, autumn, and winter, and the variations in length of day and night.

These three motions are so constant that astronomers can calculate with great exactness the position of the earth in its orbit at any given time. It is a mechanical law, easy of demonstration, that a semi-fluid mass in rotary motion produces as the result of centrifugal force on its different diameters, an increase of size towards the larger diameter of the mass, and a flattening toward the poles, or extremities of its axis.

By virtue of this law our earth, when it had cooled down to a semi-fluid condition, became swollen at the equator and flattened at each pole, and thus changed from its original spherical shape when it was gaseous to a spheroidal shape when it was fluid. It became flattened at each of its two extremities.

This spheroidal form of our earth, the swelling at the equator, and flattening at the poles, furnishes us with a simple and scientific proof, that it was in remote past ages in a liquid state.

A solid, inelastic body, or sphere might rotate on its axis for countless ages with no change of shape, but a semi-fluid, or pasty mass, would obey a fixed law of mechanics, and become a spheroid instead of a sphere. The amount of this flattening has been variously estimated, and the most accurate measurements give us about 26½ miles—that is, the polar diameter is less than the equatorial diameter by 26½ miles. This is, however, so slight as to be practically inappreciable.

As the habitat of animal life and of the causes that have led to changes in animal forms this oblate spheroidal shape of the earth is of little consequence.

It is one proof of many of the original fluid condition of what now seems to be a solid globe.

As we progress in our study of the many changes that have occurred in the earth, it is necessary that we should have clear and definite ideas of our subject. It is puerile to say that the human mind cannot grasp so vast a subject. The trained and educated mind can grasp it and easily comprehend it, and the mind can be readily trained and educated by proper and scientific methods of study so that the great laws that govern the universe and the evolution of life upon the earth can be clearly understood.

In dealing with this view of our subject, the cooling of our earth's surface, we must learn to deal with and clearly understand vast periods of time, not thousands of years, but many millions of ages, for nature moves slowly in her operations and requires for her many changes enormous lapses of time.

It is probable that the period of time from the moment that our earth was first thrown off from the sun as a gaseous mass down to the period when it became a semi-fluid, pasty mass, having its first fixed spheroidal shape, was longer in duration than all the ages that have since elapsed until to-day.

It must be computed as many millions of ages, for the reason that a mass so vast and so intensely heated must have cooled very slowly.

This cooling process must have proceeded more or less quietly, and there is little or no reason to sustain the idea that the earth ever was the scene of terrific convulsions.

The great mass slowly and silently parted with its heat, which was radiated into space. The process was a very quiet one. The rocks and metals, being the heavier, subsided towards the centre of the mass, and the gases formed a thick, hot envelope around the heated central core.

This gaseous envelope was composed of oxygen, hydrogen, nitrogen, carbonic-acid gas, and many saline substances besides, which was so dense and murky as to prevent the rays of the sun from reaching the slowly solidifying crust.

We can compare this cooling process of our molten earth to the cooling process of molten iron from a blast furnace. When it is first withdrawn from the furnace it is liquid and glowing with a brilliant and intense heat. It seethes and bubbles in parting with its contained gases, and finally settles down to a quiet cooling. As its heat diminishes, its brilliancy diminishes also, until it reaches a white heat, then a red heat, then a darker hue, until it crusts and films and begins to solidify on the surface and becomes opaque.

If it is agitated, by motion, or by chemical processes, the liquid interior may burst through the thinly formed crust, and pour itself out over it, and this may recur many times, until the crust is sufficiently thick and strong to keep it permanently confined.

Now this cooling of the melted iron, which has taken place before our eyes in a few hours, is similar to a process that has taken place in the earth during countless ages past, while it was cooling down from a liquid to a thick and strongly encrusted form.

Now another agent sprang into activity through a purely chemical process, to hasten the cooling of our earth—namely, the compound called

WATER.

We are told that *steam* existed in the thick and heavy atmosphere of the earth, and being condensed in the upper and colder air, fell upon the heated crust as *rain*. This is only a part of the truth. There is a chemical fact to be explained besides.

Steam (which is vaporized water) did *not* originally exist in the atmosphere, but hydrogen gas and oxygen gas did exist along with the other gases.

Now these two important elements or gases were present in vast quantities in those early ages. Each was a fixed and definite element or gas of immense importance. They existed as gases only, having no power of changing their properties. They were mixed *mechanically* but not *chemically*. In the constant frictional movements of the molecules composing the elements of the atmosphere there was in time generated a new chemical force which we call

ELECTRICITY.

This was produced by the friction of the particles of the various gases upon each other, and may be called *frictional* electricity.

This was a potential factor at this period of the earth's history.

Let us see exactly how water was first formed, and what is its chemical composition.

It is a fixed law of chemistry that if two volumes of pure hydrogen gas are mixed with one volume of pure oxygen gas, and the mixture ignited by the electric spark, the two gases disappear, and *water* is formed by the chemical union of the two gases. It is not a mechanical mixture; it is a chemical compound. Here we have another instance of the results of *chemical force*, the subtle power that can change two imponderable gases into a ponderable liquid. The murky gases that formerly surrounded our earth moved among themselves, and the frictional contact of their particles generated the electric spark. This acted upon the hydrogen and oxygen gases, and weds them as it were, and, see—a new and strange substance appeared, totally dissimilar from the viewless and impalpable gases that gave it birth. This is water.

Electricity re-arranged the atoms of the oxygen and the hydrogen, and water was the result. In this simple and beautiful way, obedient to a fixed and stable law of chemistry, water was first formed, and henceforth became a mighty power, and a measureless comfort. The air became a gigantic chemical laboratory working upon a magnificent scale. Water was formed in vast quantities in this way, and being heavier than the atmosphere, fell upon the heated crust of the earth. The intense heat instantly changed the water into steam, and it rose in the air as watery vapor. As it reached the upper rarer and colder air, it became condensed into water and again fell upon the crust of the heated earth, to be again vaporized into steam.

This was repeated many times. Each vaporization of the water conveyed heat from the earth into space, and each condensation of the vapor into rain carried cold from space to the heated earth.

By the aid of this process, the cooling of the earth went on somewhat more rapidly.

It had another effect. The rain continually falling through the air in deluging torrents tended to wash out and carry down with it a great part of its carbonic-acid gas, which dissolves to a limited extent in water, and also to dissolve its various salts, which it held in suspension in a state of vapor in the highly heated atmosphere.

In this way the atmosphere gradually became freed from its impurities. It was, however, too thick and heavy to sustain animal life, even if animal life had existed in that Archean age.

As the ages went slowly by the crust of the earth became cooler and the rains more abundant, until a point was reached when the waters were no longer dispelled in steam, but rested on the earth in a wide universal ocean, thick, muddy, and boiling hot.

Imagine such a scene.

The air still laden with opaque gases so that the rays of the sun could not reach the earth; a sort of dull twilight existed. A universal sea, stretching everywhere, boiling and bubbling under the influence of the great heat. Flashes of lightning illuminating the darkened air, followed by peals of echoing thunder. Deluging rains fell ceaselessly. No land or life anywhere. No one to be awed or impressed by the grandeur of such "stupendous activities" of nature. Everywhere it was solitary and desolate. Dreariness reigned supreme. It was a scene of gloomy grandeur—a wide, universal, lonely ocean.

When we speak of the tremendous activities of nature, of great dislocations and upheavals of the earth's crust, and of those fearful phenomena that have marked the geological development of the earth, it must be understood that they *appear* so to our eyes. They *seem* great to us.

In reality, these great convulsions that have occurred in the formation of the crust of the earth are very small in comparison with the size of the earth itself. Nature has worked out her great and wonderful changes in comparative quiet.

We must study these geological changes by comparison with familiar objects. The thickness of the superficial crust of the earth bears about the same proportion to it that the egg-shell bears to the egg. This is a fair comparison. If we will take a globe *fifteen inches* in diameter, and cover it with a single coating of white varnish, it will give us a very correct idea of the extent of the ocean's depth. If we will now strew such a globe with grains of coarse sand we shall have the ordinary hills and valleys now seen about us. If we strew a few mustard seeds here and there we shall have our ordinary mountains, and if we again strew a number of common dried peas we shall have the highest mountain peaks of Asia, South America, and Mexico. They shrink into nothingness when compared with the earth itself. This comparison gives us a very clear idea of the relative depth of the sea and the height of the loftiest mountain chains.

Now it will be seen that the ocean represented by a coat of varnish on a fifteen-inch globe is so small in proportion to the size of the globe that it sinks into utter insignificance. It could be dispelled in space and lost, or it could be swallowed up in the interior of the earth without any appreciable effect upon the earth itself, except as to its influence upon life. Great as the ocean appears to us, it is in reality small when compared to the size of the globe it covers, and its cooling effect on the hot crust of the earth has been *comparatively* slight. Its modifying influences on the configuration of the land have also been small, although in the lapse of ages the aggregate influences have made some changes in beaches and sea-cliffs, but it has had no effect upon changing the area of the continents. If the loftiest mountains on the earth can be compared to dried peas on the surface of a fifteen-inch globe, it will be seen that such expressions as "stupendous upheavals" are exaggerated.

It would not require any such "stupendous" force to elevate above the sea-level a mass so small when compared with the size of the earth itself. A very gentle force would be sufficient to raise so small a mass. Great mountain chains like the Himalayas, the Andes, and the Rockies, seem great to us, and in comparison with our own stature they are so, but when compared to the great mass of the earth they are almost unnoticeable, and required but a slight force for their upheaval. Even in approaching our own Rocky Mountains from the plains of Colorado they seem moderate in size, and it is only such elevated cones as Pike's Peak and Long's Peak, and a few others that are especially prominent. In engineering surveys of our continent, and in relief-charts of mountain districts, the elevations when drawn to a scale are much less prominent than we would suppose. The mean height of all the land on the earth above sea-level has been estimated to be *one thousand* feet, while the land of North America is only 750 feet above sea-level, on an average.

The comparison, therefore, of the dried peas on a fifteen-inch globe is a just one of the inequalities of the earth's surface, and conveys to our minds a correct idea of their comparative extent. This also proves that the earth must have cooled very quietly from its gaseous to its present condition, or it would have shown higher mountains and deeper valleys as the result of greater geological disturbances.

In the course of ages the universal ocean of muddy boiling water became cooler and clearer. The rains still fell in deluging torrents, the vivid lightnings still flashed and illuminated the murky air, the thunders still echoed over the lonely sea. The rays of the sun could not yet reach the earth.

It is no idle speculation to imagine such a scene. It must have been so from the nature of the physical and chemical forces then in activity. The earth was slowly evolving itself from its primitive gaseous condition to become the fitting abode of animal life, and this process must have been extremely gradual. The internal heat of the earth still kept its contents in a state of fusion long ages after the super-crusting of its surface, and this intense internal heat manifested itself for a time by movements of the crust more or less extensive, while it lay submerged beneath the universal sea. At some time during this early age when the sea had become somewhat cooler and clearer, an upward movement of the crust occurred, and we have as a result the first uplift of *dry land* above the level of the sea.

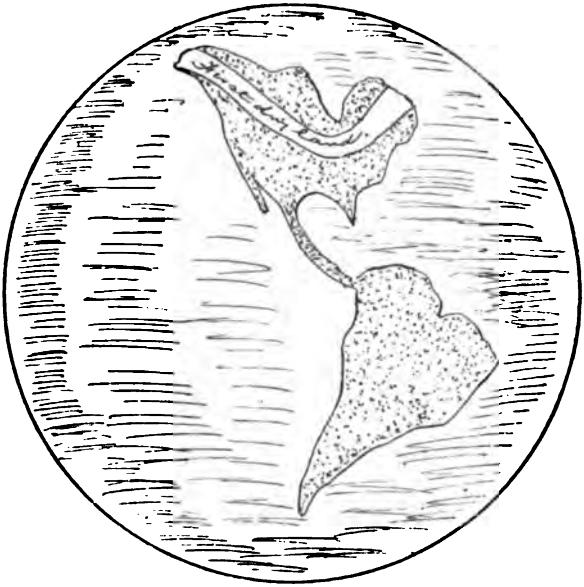


FIG. 1.—FIRST UPLIFT OF LAND IN THE SILURIAN AGE.

Geologists have called this period—that is, from the time when the earth was in a gaseous state to the time when it was sufficiently cool to be covered by water—the Azoic age, which means an age without life. As there was no land there could have been no life.

But now dry land appeared. This first uplift of the earth's crust that reared its head above this wide, this universal and lonely sea, occurred at what is called the Lower Silurian age. It consisted of a long line of low hills, commencing on the northeast at Labrador, extending in a southerly and westerly direction to the region of Upper New York and the Great Lakes, then bending to the northwest, and stretching away to the Arctic Ocean. This bow-shaped strip of land has been named the Laurentian Hills from the fact of its lying partly along the border of the St. Lawrence River and Gulf.

It formed a great barrier that divided a limitless expanse of waters into a northern and southern ocean. This strip of primitive land, the first dry land of the earth, is well shown in Fig. 1. The shaded parts of the map show the still submerged continents, over which was a shallow sea.

Through all subsequent ages, and through all the successive changes that have occurred in the earth's crust, this primal strip of land has remained quiet, stable, and unchanged.

Along the centre from east to west it had a well-marked ridge or divide, which in later ages caused its rivers to run northerly into what was later the St. Lawrence Gulf, or southerly into the Atlantic Ocean. This primal upheaval was a lifting of the rocky bed of the ocean above its surface level, through the agency of the internal fiery forces of the earth forming a rocky crest or ridge of land, and these rocks forming this ridge are called by geologists Azoic rocks.

Azoic rocks contain no fossils, nor any sign of former life, and we are certain, therefore, that no form of life then existed.

This first uplift of land above the surface of the universal ocean marked the beginning of a new geological age—the Archean or Azoic period, which was an age without life.

As time elapsed a new era dawned, and we have the advent of the Silurian Age, with its three subdivisions of Primordial, Lower Silurian, and Upper Silurian.

FIG. 2.—QUIET SEAS OF THE SILURIAN AGE.

When we walk along the shores of Lake Memphremagog, and on the shores of Lake Champlain and Lake George in Upper New York, and over the high and rounded crest or summit where Saratoga now stands, we tread on that same land that countless ages ago lifted its head above a universal sea which covered the primitive globe.

That early Silurian beach was wide-stretching and desolate and silent. Climates did not exist; a temterature nearly uniform and hot encompassed the earth. Deluging rains still fell upon it; but the thick atmosphere, heavily laden with carbonic-acid gas and mineral salts was nearly quiescent, and obscured the sun's rays.

The torrential rains served a double purpose. They purified the air by washing down many of the impurities held in suspension, such as the soda salts, etc., especially the chloride of sodium or common salt; and they slowly wore away and carried down to the sea as sediments the highest crests of the land. The contained salt in the air and in the earth's crust was gradually dissolved, and the ocean, at first muddy, hot, and fresh, grew clearer and cooler. The sediment subsided, and in later ages became intensely salt and beautifully transparent.

As time elapsed the atmosphere became cleared of its impurities, until the rays of the sun finally penetrated the clouds and reached the Laurentian Hills, whose shores lay bathed in a warm, fresh, and quiet sea. No aërial disturbances occurred, and no restless surf beat upon its shores. Such an ideal scene is well shown in Fig. 2.

In that peaceful sea, and in the little bays and inlets of that quiet coast, the first and simplest *vital organisms* found a congenial habitat, and sprang easily into existence. And it was in the Silurian age that these vital organisms actually did appear upon the earth. The later ages of that epoch, called the Upper Silurian period, was the time that a new *chemical force* came into activity, and produced that wonderful phenomenon we call Life.

CHAPTER III.

THE PALEOZOIC AGE:—THE SILURIAN PERIOD. THE ORIGIN OF LIFE.

Life believed to be a form of chemical force—Chemical compounds—Albuminoid substances — Protoplasm — Single-celled animals—Fission and growth of cells—Self-propagation—Development of the sea-worm—Masses of cells—Early plant life—Olynthus—Special activities of cells—Protozoans — Lingula — Early mollusks — Radiates — Starfishes—Crinoids or sea-lilies — Comatula — Articulates — Trilobites — Development of the eye — The nervous system—Erosion of Laurentian Hills—The Ausable chasm.

In the study of the origin and progress of life on the earth, a study full of the deepest interest, we must constantly keep in mind the many changes and varying conditions of the earth's surface. We have seen that as the result of these changes, the earth has gradually become the fitting habitat of animal life. We have a long low strip of dry land bathed by a warm and quiet sea, and lighted by the sun, whose vivifying rays now reach the surface of the earth.

Everything seems ready for the introduction of life, and we have reason to believe that at this period life appeared.

A great and immensely important question at once confronts us.

What is life?

We answer, it is a form of chemical energy or force acting on organic substances.

By what process did it spring into existence, and how did it first appear?

Undoubtedly by the operation of a fixed and inexorable law known as chemical affinity.

What is chemical affinity?

It may be defined as a peculiar and subtle force, of great energy, which causes the simple atoms of different forms of matter to unite and form new bodies or compounds unlike the original elements.

It acts at slight and insensible distances upon the most dissimilar substances, and by the chemical union of the atoms of these dissimilar substances other bodies or compounds are produced that are entirely unlike the molecules of the elements that entered into their composition.

Its operations are absolute and definite, and it has the power to cause simple elements to unite in varying proportions with other elements and form complex bodies with higher powers.

The results of its operations are well known, but the exact method or process by which atoms unite to form new bodies is invisible and unknown to us.

We have seen that water was formed by the union of two colorless, impalpable gases—namely, oxygen and hydrogen. Here a new body—a liquid—has been formed which is totally dissimilar from its two component gases.

We do not know *how* the atoms arranged themselves to form this liquid, but we do know that it was done through the agency of chemical affinity.

The laws of chemistry have a fixed formula for water, as for all substances, and a knowledge of these formulæ is so convenient that it tells us at a glance of what they are composed.

Water is thus expressed—H_2O, which is, as above stated, two atoms of hydrogen gas and one atom of oxygen gas.

Each element has its own symbol, by which it is always known. Thus oxygen is known by the symbol O, hydrogen = H, nitrogen = N, carbon = C, phosphorus = P, sulphur = S, and so on through the whole range of chemistry.

A combination of these elements produces all the substances known in chemistry. If we take H and O, and add to them C, in varying proportions, we can form a wonderful series of new and strange compounds.

For example, if we take twelve atoms of carbon, eleven atoms of hydrogen, and eleven atoms of oxygen, and unite them, we have an entirely new substance, utterly unlike the substances that entered into its composition, namely—crystalline cane sugar.

There is a formula for cane sugar, the formula being $C_{12}H_{11}O_{11}$ invariably. If we take away from this eight atoms of carbon, five atoms of hydrogen, and nine atoms of oxygen, our beautiful white crystalline sugar changes into a new body so utterly dissimilar that we do not recognize it at all—namely, alcohol = $C_4H_6O_2$. If from alcohol we remove a single atom each of H and O, we have another wonderful change, and another new body is called into existence—ether—quite unlike alcohol.

If we take a new element, nitrogen, and add it to C, H, O, in varying proportions, we can form a long array of strange and curious and interesting bodies, well known to organic chemistry.

Let us take a single atom of H, a single atom of N, and three atoms of O = $H\,N\,O_3$, and these harmless molecules unite, and we have an intensely corrosive poison—nitric acid.

If we take an atom of hydrogen, an atom of nitrogen, and two atoms of carbon, each simple and harmless elements, and combine them chemically, we produce a peculiar substance, a poison so deadly that a small quantity placed upon the tongue will instantly destroy life. This is prussic acid—$H\ N\ C_2$.

The list of new substances which may be formed by varying the proportions of C, H, O, N, in combination, is almost incredible, not only in the number of new bodies formed, but in the variety of their characters. The long array of compounds which can be thus formed is an interesting illustration of the law of chemical affinity or chemical force. But the most singular and interesting of all these chemical compounds is the group of bodies known as albuminoid substances. These are extremely important, and intensely interesting.

These substances enter largely into the formation of living bodies.

Albumen is a familiar substance to us all, and is seen in a state of purity in the white of eggs of birds and fowls. A compound of such great importance has been carefully studied, and chemists give us the following

Chemical Composition of Albumen in One Hundred Parts:

Carbon	53.5
Hydrogen	7.0
Nitrogen	15.5
Oxygen	22.0
Phosphorus	0.4
Sulphur	1.6
	100.0

It will be seen that albumen contains six elements, all of which were present in the air and water of the earth in the Silurian age. Albuminoid substances largely enter into the formation of living animals, as well as to form the most important articles of food.

We have seen, then, that this subtle force known as chemical affinity has the power to so arrange the atoms or molecules of elements that *new* and unlike compounds are formed, and that it is a law constant and fixed in its operations.

By the operation of this law, many changes occur in chemical and organic bodies. As for example—gases are changed to fluids—fluids to solids—solids to fluids—and solids to other solids, and in each case a *new* body is the result, unlike its component elements. This law has also the power to change gases into jelly-like compounds by a rearrangement of their atoms, and as a result we have an albuminous compound, called **Protoplasm.**

The chemical formation of this substance is the first step in the evolution of vital organisms, endowed with the principle we call

LIFE.

The rearrangement of the atoms of certain gases and elementary substances in such a way as to form an albuminous mass, or protoplasm, is precisely the same chemical process that takes place in the formation of sugar in the sugar-cane and many other plants, and in the formation of alcohol, of ether, of acids, and of a great number of other bodies known to the science of organic chemisty. Many of these bodies can be produced artificially in the laboratory, but in the first instance they were formed in nature's laboratory by virtue of the fixed and definite law of chemical affinity under certain favorable conditions. These conditions were found in the Silurian age.

We have seen (Fig. 2) that in the Upper Silurian period the sea was placid and undisturbed. No surging tides existed, no surf beat upon the shore. The coasts were indented with numerous, quiet, shallow bays, the air was mild, and the water was fresh and warm.

The sun's rays fell with softened and tempered heat upon the sea, and the whole earth basked in the equable temperature of a midsummer's noon. The sea, unruffled by winds or currents, was in precisely the condition to favor the formation of little masses of albuminous matter in its shallow bays and pools.

Here chemical affinity rearranged the atoms of the elements found in the water, and under conditions so favorable the little protoplasmic masses or cells came into existence.

These little masses of jelly or albumen were at first of scarcely greater consistence than the water in which they lived. They were formed by adding to the elements of the water already existing, a little nitrogen, a little carbon, some sulphur, and a trace of phosphorus.

The water, already formed by the union of its two component elements, H and O, only needed the addition of a few atoms of C, N, S, P, to form albumen.

With these added elements the new arrangement of atoms occurred, and here and there in the quiet sea the little lumps of albuminous jelly were formed simply by the chemical union of six elements—namely, C, H, N, O, S, P—obedient to that peculiar force already described.

The albuminous, jelly-like masses thus formed were bodies composed of a single cell. After they were formed a new function at once became necessary—that of ***nutrition.*** As they floated in the water they absorbed into themselves the elements of the water, and in this simple way they nourished themselves. The next step was to protect their soft and delicate bodies, and an outer covering became a necessity. This covering must be developed from the formation of a thin pellicle or membrane caused by the thickening and organization of the atoms on the outer surface of the cell.

The formation of this *cell-membrane* was the next step in the process of development. It was an important step, for, as we shall see later on, the cell-membrane played a conspicuous part in the subsequent development of some of the higher forms of early life.

A cell-membrane, to cover and protect the soft and delicate contents of the cell, having once formed upon the outer surface of the cell, it could perform the office of an absorbent and take from the water in which it lived and floated as a little delicate, independent body the nutrient materials necessary for its growth.

And this it did, as we see the amœba does to-day. The original cell was without doubt an amœboid body, and nourished itself by absorbing food through its cell-membrane.

After this *cell* reached its growth by nutrition and development it proceeded to its next step—that of propagation. This consisted of a contraction of the cell-membrane through the centre of its body, and this pinching in went on until the cell divided in the middle and two cells were formed from one.

In this way the cells multiplied. Those that were originally formed by the union of the six primary elements divided themselves into two, and this process of subdivision greatly increased their numbers.

These cells, so delicate and of a consistence but little greater than the water in which they lived, were nevertheless *veritable organic bodies*, although of simple structure and of lowly organization.

As these cells continued to increase in development the more fluid parts of their bodies were eliminated, and the soft protoplasmic mass became more firmly organized. At the same time the structure of the cell-membrane became more highly developed, serving the purposes of nutrition and growth, as well as a locomotory function, and whatever of the sense of touch they may have possessed.

The power of locomotion and palpation made them free and independent bodies.

They were in fact little animals, having an individual structure and leading a perfectly free existence in the sea.

It must be remembered that the natural tendency of organic nature, or organized bodies, is upward to a higher and more specialized development.

So our little mass of protoplasmic jelly formed in the quiet seas by the chemical union of six simple primitive elements in definite proportions—namely, C, H, O, N, S, P—and under the law of chemical affinity, had in itself the power to grow in size by absorbing into its substance the nutritive elements of the water surrounding it, and of assimilating these elements as food.

These little jelly-masses were simple cells. Each was a little organized body composed of a single cell, but they possessed an inherent power to do certain things in a physiological way, and this peculiar power or activity to do these things we call Life.

Each of these cells, though simple, was complete in itself, and was an animal possessing vitality and the power to nourish and propagate itself.

There can be no reasonable doubt that this is the process by which that peculiar vital phenomenon to which we have given the name of *life* first appeared upon the earth. Let this process be clearly understood. There is no mystery about it. It is plain and easily comprehended. It is the result of a fixed and definite chemical law.

It is true that we do not know just *how* the atoms of the six elements are arranged to form protoplasm. Neither do we know just how they are arranged to form cane sugar, or alcohol, ether, acids, nor any of the vast array of bodies known to organic chemistry. But we do know that they *are* arranged to form all these bodies, and that they are so arranged by the influence of chemical action. We see to-day in fresh water the one-celled animal called an **Amœba.** We know he is formed by the union of certain elements, but we do not know how the atoms of those elements are joined to form the animal. It is certain that they are formed by a chemical process, and the process has been the same from the first cell to the last.

If we have established the fact, that vital organisms owe their origin to the operation of a chemical law, and if we have clearly demonstrated it by a reference to known scientific facts and logical arguments—and we think we have done so—let us proceed upon this same basis of reasoning to establish the law of evolution, and see if it can account for the development of the whole animal kingdom, through all its successive changes, from the single-celled animal up to man. Our original little, jelly-like mass is, then, an animal composed of a single cell, endowed with a vital principle we call life, and possessing the power of nutrition, growth, and self-propagation.

The propagation must have been *asexual*, or without sex, for sexes could not have existed at this early stage of life.

This process of propagation by one cell dividing itself into two has been called *fission*, and this peculiar power of fission plays an exceedingly important part in the early development of life on the earth, and in the processes of early embryonic life throughout the whole range of the animal kingdom.

The method of self-propagation of a **Moneron**, or a single-celled animal, by fission, is a subdivision of itself into two or more parts, by a growth of these little organisms beyond their own individual limits of size. When they reach a size which limits their further growth, they immediately subdivide themselves, and two individuals are formed in place of one. We see the steps of this process in Fig. 3.

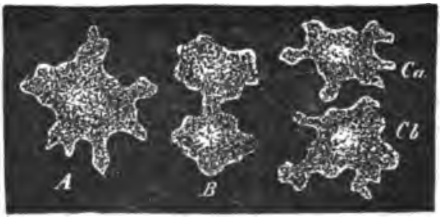


FIG. 3.—FISSION OF THE CELL.

This method of propagation by self-division is a physiological function, and is one of the most widely spread and universal in the whole domain of the minute animal world, for by this process cells multiply themselves, and single individuals become the parents of many.

Cells possess the power of development and growth, and this power causes them to become more highly organized, until finally we have a cell which is a complete individual in itself.

As a higher grade of development is reached, and a higher order of individual—or one composed of many single cells—is formed, these component single cells, that propagate themselves by self-division, thus giving rise to new cells, retain these new cells in contact with the parent cells, instead of separating into solitary cells, and by thus *aggregating* themselves into masses, they form a more complex individual, a community, or a state.

In order to form a more complex individual, or one composed of many cells, in the upward course of development, a new function arises, whereby each cell composing the mass does a special thing, or a special kind of work, and this is known as a *physiological division of labor.*

The different forms that masses of cells assume, and the vital phenomena of all organisms composed of many cells, are merely the expression of all the forms and all the vital phenomena of all the single cells which compose them.

All animals are developed from the egg, which is a true cell, and the egg, whether that of a moneron or a man, is a cell—either single or aggregated, with its central protoplasmic mass, surrounded by its cell-membrane. When this central mass subdivides, its parts remain within the cell-membrane, and by a physiological division of labor organize themselves into the component parts that form the new individual.

The single cell, then, is an animal with complete physiological functions in itself. It has the power of nutrition and growth. It can subdivide itself into two or more parts, each part like the parent cell *inheriting* the same qualities of nutrition, subdivision, and growth. It can transmit its qualities to successors. The simple cell develops in a later age into the more highly organized *egg*, and this by its greater subdivision represents, at the beginning of our individual existence, the very same physiological process that develops all animals—whether a dog, cat, horse, ape, or man.

The simple cell soon develops another quality besides those of nutrition and growth. It has the power to attach itself to other cells, and form a line of cells, like a string of beads. In this way a more complex animal, a **Sea-Worm,** is formed.

FIG. 4.—STRING OF CELLS FORMING A SEA-WORM.

In this way we have the next step in animal life, a sea-worm, formed by a few cells attaching themselves together in a row.

This step no doubt began by *two* cells forming such an attachment, then others were added, until as a result we have our simple worm. This worm gradually developed a special activity—that of motion—which enabled it to swim about freely in the sea, in search of food.

Here is a step in advance in the evolution of life.

The next step was a number of cells grouping themselves together, not in a row, but in a mass, and this group of cells foreshadows another form of animal life, as it also foreshadows *plant life.*

It has been a question among biologists whether animal or plant life first appeared on the earth. We shall endeavor to show that the cell which was at first an animal soon began to develop also into a plant, so that, thereafter, animal life and plant life proceeded to a higher development simultaneously.

There is a little creature belonging to that group of animals called **Sponges**, which has received the name of **Olynthus.** It is a group or mass of cells, adhering to each other and all looking alike. The mass somewhat resembles a mulberry. The cells on the outside of this mass soon develop a special activity. They thrust out tiny prolongations of their cell-membranes, which soon become developed into cilia or hair-like processes, and these, vibrating to and fro, act like little oars and propel the little creatures through the sea.

By and by, another change comes. The central cells arrange themselves to form a central cup-shaped cavity, and the animal now attaches itself to a rock in the waters of that quiet Silurian sea. Some of the cells nearest the rock soon subdivide, until a short stem or footstalk is developed.

Now that the animal is stationary, and needing no longer the propelling cilia, they disappear, by the law of *disuse.* As the animal can no longer travel about in search of food, its food must be brought within its reach. We soon find a special adaptation to this end. Small apertures appear in its sides, and the cells lining its cup-shaped cavity develop cilia, precisely as they were developed on the outside. The vibratory movements of these cilia maintain a current of water through its body, and our olynthus is nourished by a supply of food.

The development of this little creature is very interesting. A single cell subdivided itself into many, all exactly like the parent, and all doing the same thing. Soon some of the cells develop a special activity and a special apparatus for performing particular movements and functions. This activity induced a change in the form of the cells and a special development of certain parts which marked its advance to a higher type of animal life.

We now come upon a great principle, clearly illustrating the fact that the steps between the lower and the higher types of animal life are progressive, and strongly influenced by the special needs of the animal.

The difference between a simple cell and our sponge —that which makes the latter a higher type of life than the former—is that a certain number of its cells are set apart to perform a certain kind of labor.

They have developed a special activity to meet the needs of the higher animal. The single cell moves, but the sponge moves more rapidly, because it has developed special organs of locomotion—the cilia. When it has attached itself to a rock, its locomotory apparatus disappears. It seeks its food by a new process, but its digestive powers are only the sum of the digestive powers of the single cell.

In Fig. 5 we see these groups of cells attaching themselves to rocks in the quiet waters of the primitive seas, to form our olynthus or sponge.

The development of the olynthus takes place before our observation to-day. We see the groups or masses of cells of a mulberry shape, in the quiet seas of our coasts, and by confining them in captivity they pass through the various phases of their existence—the development of the locomotory cilia, the attachment of the mass to a rock by means of the growth of a footstalk, the disappearance of the external cilia, and the formation of internal cilia, and the lateral apertures for the passage of the water into the cup-shaped cavity of the animal.

Is there any evidence that this process took place in the Silurian age? It is known that the olynthus and other forms of sponges, when they reach maturity, absorb from the water a quantity of lime and silicon which they deposit in their walls in the shape of spiculæ or needles. This forms a hard unyielding wall which retains the shape of the animal. It is composed of silicate of lime, and is therefore very enduring.

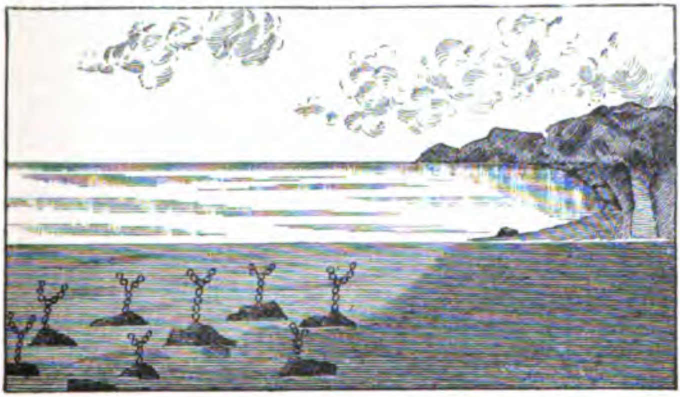


FIG. 5.—SPONGES GROWING ON FOOTSTALKS IN THE SEA.

Geologists have found the siliceous sponge casts in the lower strata of rocks, some of them in a state of complete preservation.

As we come to the Cretaceous period we find the sponges in a still better state of preservation. In the strata of that age we find them cup-shaped like the original olynthus, and saucer-shaped, and of many other shapes besides, and in great abundance. These fossil sponges have been found in the late Tertiary strata; and so we have evidence left us in the rocks that the sponges began their existence very early in the history of life, and have continued it onward to our own time.

The lowest form of *plant life* is found in the **Algæ** or **Sea-Weeds.** Here the cell attaches itself to other cells, to form a row, as in the sea-worm; but instead of developing the power of motion, they attach themselves by one end to the rocks, and enter upon a new phase of existence. The cell-membrane which adjoins where two cells are in contact, is absorbed and disappears, the rest of the cell-membrane remaining intact. In this way a pervious tube is formed, and we have the simplest expression of plant life, a straight tube or stem formed of many cells.

These processes of the development of animal life and plant life go on from this early point simultaneously. A long period of time is required, but there is ample time in the Silurian age and the ages which succeed it.

The sponge growing on its footstalk in the quiet seas of that remote age had abundant time to develop into higher and more special types of existence.

The straight tube, composed of a row of cells which formed the first plant, developed in a later age into the **Crinoids,** or **Stone-Lilies,** and later still into the more complex forms of higher vegetable life. Many lowly forms, intermediate between the sponges and some of the higher animals, doubtless existed, and having reached a certain stage of development, passed away. Many of these forms, no doubt, were the result of exuberant development, and became extinct before they reached full maturity. The fossil remains of these lower types of animal life show that the course of evolution was ever upward, from the simple to the complex and more elaborate organisms.

They are steps in the scale of development, and show that the evolution of life was regular and orderly.

Nature is extremely prolific in her production of the lower organisms. The vast profusion of the smaller fossils we find so often give abundant evidence of that fact. The **Coral Polyps,** for example, have formed reefs of immense extent out of their limestone remains. The tiny shells, known as nummulites, have formed the summits of great mountain ranges in Europe, Africa, and India ; and the extensive chalk cliffs and siliceous deposits, found so abundantly over widely extended areas, are formed also of the tiny shells of animals that flourished in past ages. In many of the lower minute animal forms millions of individuals are produced, and in some of the higher and modern types, myriads are produced, while comparatively few reach maturity. This is true of some fishes—notably of the cod and the shad. Both these animals produce annually millions of eggs. We know many are lost, or the sea would be over-populated with these two varieties alone.

The laws that govern the evolution of life show a constant tendency to advance to a higher grade of development, to the production of more advanced forms and a higher specialization of function. The component parts, or the cell-life of the earlier organisms, constantly manifest a more perfect and complete physiological division of labor, whereby certain parts do a special thing, a particular kind of work, while other parts do another special thing, and this special activity of organs or parts advances the anatomical structure and physiological function from a lower or simple to a higher and more elaborate form. It is this principle that has caused all the successive changes that have occurred upon the earth throughout the whole vast domain of the animal and the vegetable world.

The sea-worm, composed of a string of simple cells, like a string of beads, has left his record in stone. His soft body burrowed in the soft mud, and this mould-like imprint has hardened into stone, which has come down to us perfectly preserved through all the intervening ages.

He soon developed a tendency to a higher form, and a more complete development. This upward tendency resulted from the power of the cells to become, as above stated, more specialized, and to assume more intricate functions. The physiological division of labor in the cells of the sea-worm assumed greater activity, and this increased activity led to the development of newer and more highly organized functions of the animal.

To the simple row of cells composing the worm, were soon added others, by the process of subdivision and increased growth, and we have, what later on became a head, a larger and more specialized cell.

As the worm moved about in the water it would naturally develop one end more than another, and this more highly developed end would assume a greater activity and ultimately become a *Head*. This is one of the first steps towards *Cephalization*. The head results from the anterior cells becoming more active and assuming newer functions adapted to the needs of the animal.

As this creature moved about in the water by a simple undulatory motion, the law of *use* came into activity, and the enlarged anterior cell pushed out delicate lateral prolongations of its cell-membrane which gradually developed into additional locomotory appendages. It has now independent swimming organs, and is a step in advance in the scale of animal life over his predecessor, the sea-worm. Besides the animals composed of a single cell, the sponges composed of a group of cells, the sea-worm, and the higher form with its lateral swimmerets, there were a host of lowly organized animal forms, systemless animals, of many varieties of shape. Their delicate forms, minute and microscopic in size, have been preserved to us in fossil stone.

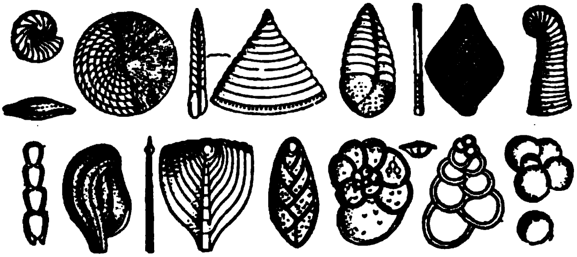


FIG. 6.—GROUP OF PROTOZOANS.

This extensive group of little systemless creatures, and others more specially developed, have been called **Protozoans**, or the first forms of life.

A reference to Fig. 6 will show how numerous these forms were, and how intricate they became even in that early age.

Many of these protozoans early evinced a tendency to protect their soft bodies with a harder covering, and the thin and delicate membrane surrounding them developed a firmer consistency by absorbing lime held in solution in the water. This calcareous shield was the first step towards the development of a shell.

Among the higher protozoans was an animal to which the name **Lingula** has been given. This little animal was originally a small group of cells attached by a footstalk to the rocks in the sea, just as the sponges were. The cells on the outside of this mass took upon themselves a special labor, and from the soluble lime in the water they elaborated little by little a hard covering or shell. These shells were no larger than the little finger nail, and their gradual growth is seen in their delicate markings.

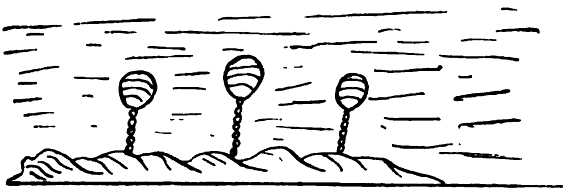


FIG. 7.—LINGULA GROWING ON ITS FOOTSTALK IN THE SEA.

These little shells so fragile and delicate in structure increased so rapidly that their fossil remains formed vast masses of stone, which has been called *Lingula* sandstone.

The footstalk on which they grew also became calcareous in structure, and as the animal matured it became broken off and fell into the soft mud and sand and was buried. In the course of time this mud and sand hardened into stone, enclosing their fossil remains. Thus were formed the early **Mollusks,** which were followed later by the crinoids or sea-lilies, the many varieties of snail, and the scallops, oysters, and clams.

During this Upper Silurian epoch there appeared besides these lowly organized animal forms we have described, and at the same time with them, the **Radiates**, and among these were the simple **Star-Fishes**, which have continued throughout all the ages, and have come down to our own times.

The first star-fishes were a lowly order of animal life, and were formed by masses of soft jelly-like cells developing a more advanced set of locomotory appendages. It will be seen that such a mass of cells, clustering together in the water, would be compelled to move about in search of food, and in doing so would soon push out first at one point and then at another a prolongation of itself, and these moving in the water as swimming organs would in process of time and by the law of *use*, become permanently developed as *rays* or *arms*, and thus we have the primary evolution of the early star-fish, one of the first of the order of radiates. These prolongations forming the arms or rays of the star-fish, at first soft and only covered by the delicate cell-membrane of the cells composing it, would, in the course of time and by long-continued use, acquire a firmer consistency, until they became thick and strong as we now see them.

A more complete development and a more complex organization of this animal is seen in the modern species of star-fishes.

In Fig. 8 we see the completely developed modern star-fish. This radiate is the same species that lived in the Silurian age, and that remote animal has transmitted to modern times the same qualities that were first manifested in him. In our own waters this creature is found in vast numbers, and has assumed predatory habits on the oyster-beds that abound in the waters of our bays and coasts.

The delicate shell of the lingula was also formed from the original cell-membrane that surrounded the mass of soft cells composing its body. This cell-membrane, instead of becoming thick and leathery like the star-fishes, developed a tendency to absorb lime which the water held in solution, and gradually elaborate it into a shell to protect the soft and defenceless body of the tiny animal. In like manner the shell of the snail, scallop, oyster, and clam, and all the multitude of curious and beautiful univalve and bivalve mollusks

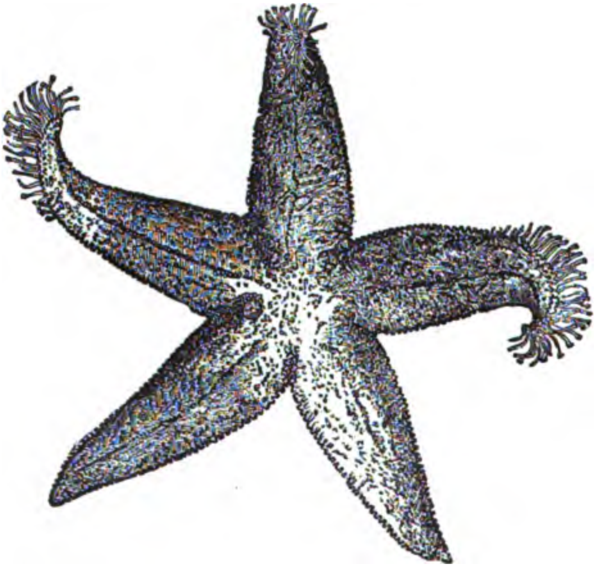


FIG. 8.—STAR-FISH.

was formed. In each of these animals the cell-membrane in the early stages of its development assumed the power to absorb and organize lime held in a soluble condition in the sea, and to slowly build it up into the hard and enduring forms now seen, with the beautiful colors and highly complex shapes that so many of them possess.

This wonderful complexity of form and figure, the variety in size, and the singular beauty of coloring seen in some of the collections of shells in our museums show how lavish the processes of evolution are. All of them were formed in the same way by the development of a special tendency of the animal to elaborate out of the lime dissolved in the water the hard permanent shells, of almost countless variety of form, that make up the vast order of mollusks. Another form of life appeared in this epoch, an animal which has been called a crinoid or a sea-lily from its resemblance to a lily. The crinoids or sea-lilies were at first like our sponges and our lingulæ, little masses of soft protoplasmic cells, which first developed the stem or footstalk, and this enabled them to attach themselves to the rocks on the bed of the shallow and quiet sea, where the conditions were favorable to their full and complete development into the many diverse forms assumed by them.

The elaborate structure of the crinoids was the result of a special activity of some of the cells composing them, and a special growth of others, and a division of labor manifesting itself where certain parts assumed the office of greater development in producing petal-like processes, and others of absorbing lime from the water and storing it up into hard and stony lily-like forms. These plant-like animals were of various and elaborate shapes as we see in their abundant fossil remains. The *cup-shape* was the form assumed by *Olynthus* and most of the early sponges, and this figure has been transmitted to our own times.

It was the form assumed by the crinoids also, a cup-shaped stony lily, supported on a long slender stony stem or footstalk, *an animal turned to stone.*

In Figures 9 and 10, we see several varieties of these interesting and beautiful animals. So many forms show at once that they lived and flourished amid the most favorable conditions. The advance from a mass of soft cells to the perfect crinoid was very great. These animals remained during the whole or a part of their lives attached to the rocks by their footstalk. As they could not seek their food, it must be brought within their reach, and we see a special apparatus designed for that end. The mouth of the creature is in the centre, and the arms, or petal-like rays radiating from it on all sides, and covered with vibratile cilia, maintain a constant current of water towards it, and thus bring food for its nourishment.

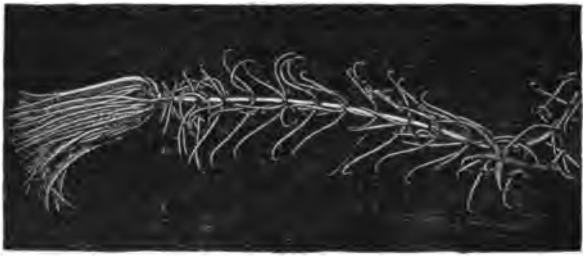


FIG. 9.—CRINOID.

The pretty little creature with ten wavy arms in the figure below is a variety of crinoid, and has received the name of **Comatula.** As it reaches maturity, it detaches itself from the parent stem, and ever after wanders free to seek its food in the water by a perfectly independent existence. The comatula does not propagate itself, but is developed from the parent crinoid.

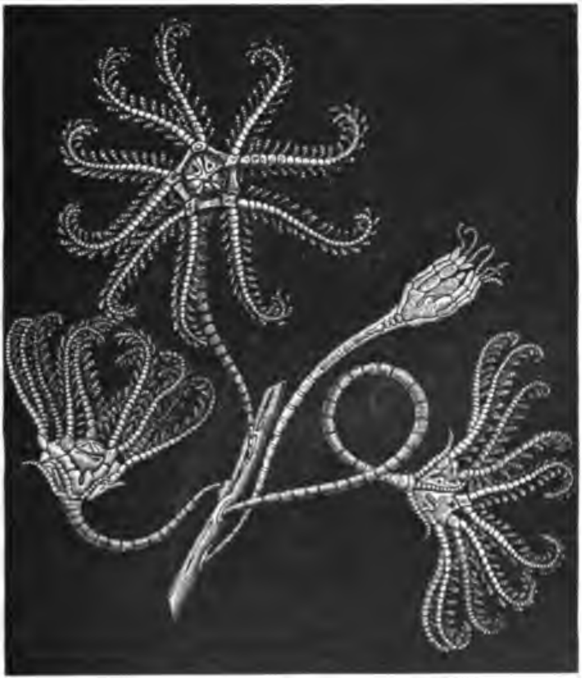


FIG. 10.—COMATULA.

All these forms of crinoids are now extinct, except the long slender form seen in Fig. 9 with the pretty delicate side branches. This is still to be found in the warm waters of the West India seas.

In the groups of radiates we see a variety of forms of this lowly organized but interesting order of animals. We see among them a similarity of plan. All are constructed on the *radiate* type, with the mouth as a central aperture, surrounded by wavy arms, or *tentacles*, which by creating a current of water by their motion, bring a supply of food to the animal. We see thus early the evolution of the tentacle, and also certain lines of development of animal life.

These lines of development very early in the Silurian age manifested themselves. The general plan of structure of the more lowly organisms is strikingly alike. The protozoans are all constructed on the same general plan, but in one of them—the sponge, growing on its footstalk—we see the next higher order—the radiates—clearly foreshadowed. The polyps, sea-urchins, star-fishes, lingulæ, and the crinoids or sea-lilies, all have the radiate structure, and are developed on the same general plan.

This order of animals, with its special radiated type, is one of the earliest instances of the formation of what may be called radical groups of animals, or where a certain special type of animal form sprang from a *common stock*. We shall see this idea more clearly set forth when we come to consider the great groups of mammals that appeared in the Tertiary and post-Tertiary epochs.

The lingula, with its delicate but perfectly formed shell of a bivalve type, is the first of the mollusks, and this animal stands as the progenitor of the long array of mollusks that appeared in subsequent ages, both of the univalve and bivalve plan of development.

The crinoids, with their radiate structure, and plant-like form, plainly foreshadow vegetable life, which appeared in a subsequent age when the terrestrial conditions of the globe were better suited to its growth.

In the quiet shallow bays and pools on the Upper Silurian sea-coast, another form of animal life was evolved, namely, the **Articulates.** Among this extensive order was an animal known as a **Trilobite.** The earliest of these were tiny, delicate creatures not more than one sixth of an inch in length. They were little masses of soft, jelly-like cells living in the warm and quiet seas of that long-past age.

By the same anatomical development we have already studied in the evolution of the sponge, the lingula, the star-fish, and the crinoid, these animals also developed a tendency for some of the cells to do a special thing, to take upon themselves a physiological division of labor, and as a result we see the cell-membrane of the outer cells of the animal becoming thickened until a crust is formed, and this crust serves to protect him from harm. The formation of this crust is due to increased activity and greater nutrition of the cells composing the cell-membrane. The movements of the animal threw this crust into folds or creases, and in the course of time these markings became permanent, and conferred upon him his distinctive name, the trilobite, or three-lobed animal.

During the long ages of the Silurian period, the trilobites found a congenial habitat, and surroundings free from destructive agencies, in the quiet seas of that epoch. Thus favored, they increased prodigously both in size and numbers.

Their distribution was extensive. Their fossil remains imbedded in stone have been found along the shores of nearly the whole extent of the Laurentian Hills. Some of them attained a length of three feet, and they must have actually swarmed in those early Silurian seas. The crust of the larger trilobites was quite thick and resisting, and here we see again a foreshadowing of the crustaceans, such as the crab and lobster, which appeared in a subsequent age.

The fossil remains of the protozoans, the lingulæ, the crinoids, the trilobites, and the other early forms of life that have been preserved to us, show no trace of a nervous system, and this is not to be expected, since nerves and nerve centres are so soft and perishable. But it is not to be doubted that the special activities in the protoplasmic cells that led to constantly higher and more complex functions in animal life, led also to the formation of a nervous system. This system, which must have been at first extremely simple, consisting perhaps only of a sensitive spot of integument, which was sufficient to subserve the needs of the animal, developed into more elaborate functions as the animal scale progressed to a higher level.

As the anatomical structure and physiological functions of these early animals developed, a system of nerves, or sensitive areas, became necessary to protect them from harm and to impart motion. The primitive cell, surrounded by its cell-membrane, possessed the power both of sensation and motion. Each of these functions was developed in the external cell-membrane. A sensitive spot on some part of the membrane was all that was necessary. But as animal life advanced, something more than a sensitive spot was needed, and certain cells assumed the functions of *nerve-cells*. These nerve-cells increased in numbers and importance as the animal developed, until a definite system of nerve-cells and nerves were formed to supply the needs of the animal.

The development of a nervous system had much to do with the progress of animal life from a lower to a higher scale. A nervous system elaborates intelligence, and the more complete the nervous development is the greater the amount of intelligence. The elaboration of a nervous system soon led to the aggregation of nerve-cells into masses at certain parts of the animal's structure, and these masses soon determined the location of the *head*. This was one of the earliest steps towards cephalization, or the formation of a brain.

The trilobites were among the earliest of the primitive animals to develop an *Eye*. The evolution of the eye as a visual organ could only have taken place after the atmosphere was sufficiently clear to permit the rays of the sun to reach the earth's surface. An eye could only be developed when there was light enough to see. In a thick and dark atmosphere an eye would have been useless. But as the atmosphere became clear and the sun's rays reached the earth, an eye became necessary.

The development of the eye as an optical instrument followed the development of the nervous system, and was stimulated by the needs of the animal to see in a clear and sunlit atmosphere. This need soon led to an increased activity and a more special labor of some of the anterior cells of the head, and these cells establishing, through the sensitive external membrane, a special line of communication with the nervous system, led gradually to the development of the eye.

Here is a striking instance of the *adaptiveness of nature*—the development of a means to accomplish a special end.

The eye of the trilobite gradually assumed a conical shape, and developed many facets or lenses, enabling the animal to see in every direction at once without changing the position of its rigid and unwieldy body. The increased range of vision compensated for the immobility of the body. Vision was not required on the inner side of the eye, and hence in that situation no visual lenses were developed. Here is an instance of the economy of Nature. She does not develop needless parts.

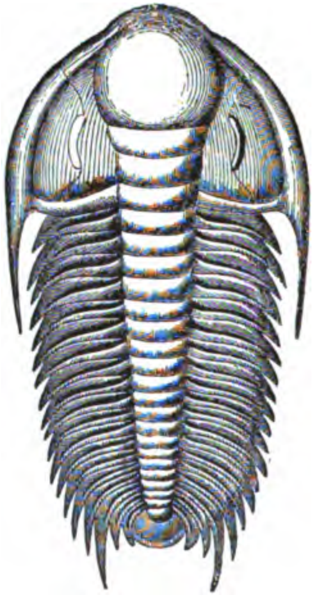


FIG. 11.—TRILOBITE.

The trilobite is seen in Fig. 11. It is said that more than four hundred species of this prolific animal have been discovered, and its fossil remains that have been found are so well preserved that its growth from the egg to the adult animal has been more accurately traced than that of any other of the early crustaceans. Some of them could roll themselves into a ball, a movement that has been transmitted to later species of animals. The head in some species presented a shield or crescent form.

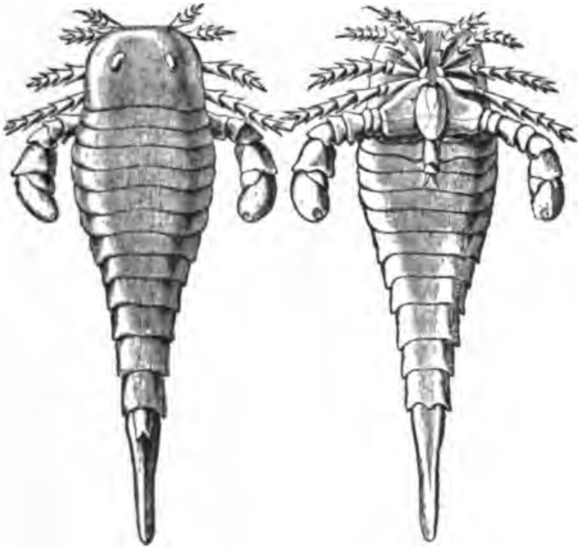


FIG. 12.—EURYPTERUS REMIPES.

Another curious crustacean was found in those early Silurian seas.

These animals, so well depicted in Fig. 12, bore no resemblance to the trilobites, but were of a higher order of life. The cut shows them of a natural size.

In this singular crustacean we see more completely developed locomotory appendages, admirably adapted for crawling and swimming in the shallow pools and bays of that period. The outer crust, which is arranged in circular plates or rings, with overlapping edges, is well adapted for the protection of the soft body within. This crust was formed by a special development of the outer cell-membrane, a natural hypertrophy of the part, this portion of the cell-membrane being endowed with the power to elaborate a thickened outer covering for the protection of the animal. The movements of the body imparted to the crust while it was flexible a number of folds, and these became at a later stage the overlapping plates covering the body.

In this crustacean we see the beginning of that long line of crustaceans that end in the prawns, shrimps, spiders, crabs, and lobsters of our own time. None of the trilobites have been preserved to our own time. They arose by the law of evolution, from a preceding form of life. They flourished, and multiplied in vast numbers, because they found a congenial habitat in the quiet bays and pools and the warm waters of that Upper Silurian sea. The temperature of the air was equable, food was abundant, and they enjoyed immunity from dangerous enemies. All these were powerful factors favoring the rapid increase of animal life.

In the course of time they passed away, and we find their fossil remains in great numbers over extended areas of the earth's surface, notwithstanding the fact that many millions of years have passed away since they became extinct.

The perfect state of preservation in which we find these fossil trilobites shows how quiet and stable that early uplift of land has remained during the great geological changes that have occurred elsewhere in the long subsequent ages that have since elapsed.

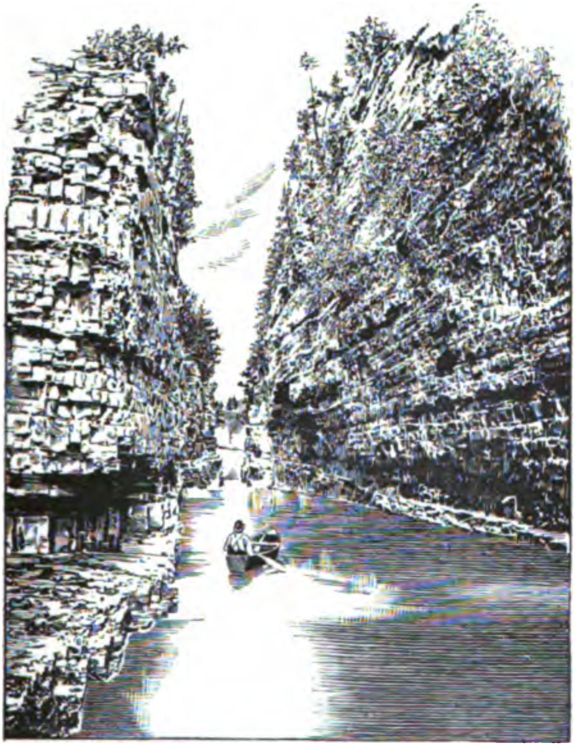


FIG. 13.—HORIZONTAL LAYERS OF POTSDAM SANDSTONE—AUSABLE CHASM.

The geological changes that have taken place in the Laurentian Hills since their first elevation above the surface of the primary universal sea, have been mainly those of erosion.

The higher elevations of land were eroded by the long-continued rains, and washed down as sand and mud into the shallow adjoining waters.

Here it was spread out into layers superimposed upon each other, and in process of time it hardened into stone.

The southern slope of the Laurentian Hill formation comprises part of the northern portion of the State of New York. Here we have a clear idea of the erosive action that occurred in the Lower Silurian epoch, in the rocks of the Ausable Chasm, near the westerly shore of upper Lake Champlain.

These rocks are of Potsdam sandstone, and lie in thin horizontal layers, varying from six inches to thirty-six inches in thickness.

The thickness of the entire Potsdam formation is not accurately known. That in New York State is about six hundred feet, but along the Appalachian range of mountains it is about seven thousand feet thick.

In Fig. 13 we have a very good view of the laminated character of these rocks as they now appear in the Grand Flume of the Ausable Chasm.

In Fig. 14 we have another view of the same chasm, showing the great thickness of these superimposed beds. We can also see how evenly the eroded material was spread out on the floor of the sea in successive layers, where it slowly hardened into enduring stone.

When treating of geological changes that have occurred in the earth's history, and of the evolution of life upon its surface, we are accustomed to deal with long periods of time. Not of centuries, nor of thousands of years, but of millions of ages.

The changes that occur in animal forms are exceedingly slow. They require many thousands of ages.

The evolution of a higher form of life from a preceding lower form demands long periods of time for its accomplishment.

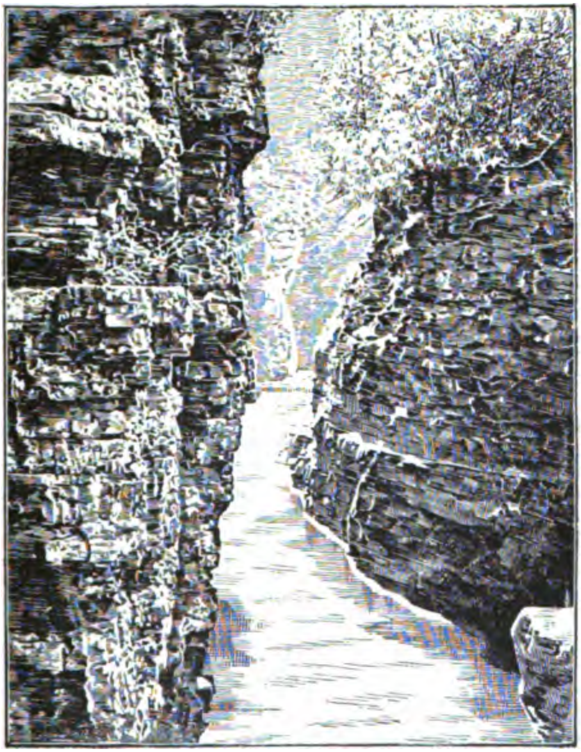


FIG. 14.—HORIZONTAL LAMINÆ IN WALLS OF AUSABLE CHASM.

But it is orderly and sequential, not abrupt, or mysterious.

These changes are anatomical and physiological, and are brought about by natural causes, and are wholly within the grasp of our reason. We have only to study them patiently and scientifically to understand them.

Some idea may be gained of the vast length of the Silurian epoch by a study of a single one of its features, namely, the Potsdam sandstone, the base of the Lower Silurian, as shown in Figs. 13 and 14 of the Ausable Chasm.

After the Laurentian Hills were raised above the primitive sea they began at once to suffer erosion from the rains that fell upon them. These rains slowly wore away the highest portions of the rock and washed it down as sand and mud and deposited it in even horizontal layers in the adjacent sea. This erosion and deposit went slowly on until the fine sandy material reached a thickness of about six hundred feet. In the course of the ages these strata hardened into stone, and later were raised above the sea-level, by the force of an upheaval, to where they now rest. This was at the beginning of the Silurian age.

Let us fully understand this fact.

The solid azoic rock was slowly and mechanically dissolved by rain, and washed down gradually into the bed of the sea, where it attained a thickness of six hundred feet. It then turned again to rock (sandstone), and was again elevated to a height above the sea.

This was a slow process and required an immense lapse of time.

In the course of these slow terrestrial changes there was ample time for the evolution of life, and the many changes from the primal protoplasmic cell to the more highly organized trilobite and the **Eurypterus Remipes.**

At the close of the long Silurian age these crustaceans, which had already reached their highest development, began to disappear. Changes in the formation of the land, the filling up of many of the shallow bays and pools in which they lived, by sedimentary deposits, and the appearance of predatory enemies, led to their gradual extinction. Their exit from the stage of life was not sudden or abrupt. It was gradual and extended far into the Devonian age. But they ultimately disappeared and left their record in stone, silent and truthful witnesses of the active evolution of animal life in a long past geological age.

Science has divided the geological epochs into distinct ages, which are convenient when referring to the development of the successive forms of animal and plant life.

They are as follows :

1. Azoic	age	or age without life.
2. Silurian	"	" " of Invertebrates.
3. Devonian	"	" " " Fishes.
4. Carboniferous	"	" " " Coal Plants
5. Reptilian	"	" " " Reptiles.
6. Mammalian	"	" " " Mammals.
7. Quarternary	"	" " " Man.

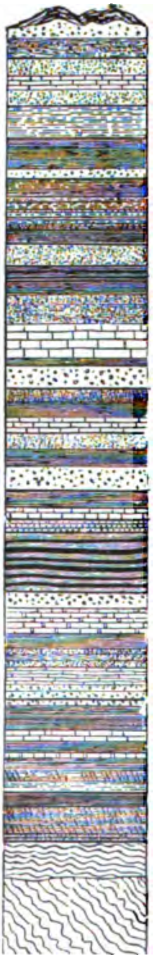
The animal kingdom has also been conveniently divided into orders and species as follows :

ANIMAL KINGDOM OR FAUNA.

SUB-KINGDOM :

1. **Protozoans**—Cells, Microscopic Systemless Animals, Multiple-cells, Sponges.
2. **Radiates**—Polyps, Sea-Urchins, Star-Fish.
3. **Mollusks**—Snails, Scallops, Oysters, Clams.
4. **Articulates**—Insects, Spiders, Crabs, Lobsters.
5. **Vertebrates**—Fishes, Reptiles, Birds, Mammals, Man.

EVOLUTION OF LIFE.



Quat'y.	**Age of Man.**					**Man.**
			Recent.			Apes, Tapir, Peccary, Bison, Llama.
	Age of Apes.	Cenozoic.	Post Tertiary			*Equus.* *Megatherium*, *Mylodon.*
Tertiary.	**Age of the Great Mammals.**		Tertiary.	Pliocene.	Equus Beds. Pliohippus Beds.	*Equus*, *Tapirus.* *Elephas.* *Pliohippus*, *Mastodon.* *Protohippus*, *Aceratherium.*
				Miocene.	Miohippus Beds. Oreodon Beds. Brontotherium B.	*Miohippus.* Edentates, *Hyænodon.* *Eporeodon*, *Hyracodon.* *Mesohippus.*
				Eocene.	Diplacodon Beds. Dinoceras Beds. (Green River B.) Coryphodon Beds	*Epihippus.* *Tinoceras.* *Orohippus.* *Eohippus*, Monkeys, Carnivores, Ungulates, Rodents, Serpents.
Secondary.	**Age of Reptiles.**	Mesozoic.	Cretaceous.		Lignite Series.	*Hadrosaurus*, *Dryptosaurus.*
					Pteranodon Beds.	Birds with Teeth (*Odontornithes*), *Hesperornis*, *Ichthyornis.* Mosasaurs, Pterodactyls, Plesiosaurs.
					Dakota Group.	
			Jurassic.		Atlantosaurus. B.	Dinosaurs, *Nanosaurus.* Turtles, *Diplosaurus.*
			Triassic.		Conn. River Beds	First Mammals (Marsupials), (*Dromatherium*). Dinosaur Footprints, Crocodiles (*Belodon*).
Primary.	**Age of Coal Plants.**	Paleozoic.	Permian.		Permian.	Reptiles.
			Carboniferous.		Coal Measures.	First Reptiles (?)
					Subcarboniferous	First known Amphibians (Labyrinthodonts).
	Age of Fishes.		Devonian.		Corniferous.	
					Schoharie Grit.	First known Fishes.
	Age of Invertebrates.		Silurian.		Upper Silurian.	Origin of the Protoplasmic Cell and Protozoans.
					Lower Silurian.	
			Cambrian.		Primordial.	
	No Life Known.		Archæan.		Huronian.	
					Laurentian.	

SECTION OF THE EARTH'S CRUST.

To Illustrate the Succession of Life on the Earth.

These five subdivisions of the animal kingdom show a regular gradation of the forms of life from a single-celled animal up to the complex organism called man.

We have now traced step by step, with sufficient minuteness of detail, the different processes that led to the formation of the primal protoplasmic cell, by the chemical union of the elements of matter. We have seen that *life* first manifested itself in a simple cell, that succeeding steps evolved a sea-worm, a sponge, a lingula, an alga, a crinoid, a trilobite, and a whole host of invertebrate animal forms besides. These forms of life abounded, they flourished and grew amid favorable conditions. Some were destined to transmit themselves to succeeding ages, others became extinct and have left their history in stone. The earth advanced, and a new species of animal life was soon to appear—namely, the **Vertebrates.**

CHAPTER IV.

THE PALEOZOIC AGE:—THE DEVONIAN PERIOD. THE EVOLUTION OF THE VERTEBRATES.

Evolution of the early fishes—The ball-and-socket vertebræ—Bony vertebræ—Heterocercal tails—The egg—The blastoderm—The dorsal plates—The medullary canal—The spinal cord—The chorda dorsalis—Devonian fishes—Cephalaspis—Gar-pike—Early marine plants—Crinoids—Comatula—Pentacrinus—Coral reefs—Coral animals—Astræans—Meandrinas—Porites—Madrepores—Millepores—Sea-fans—Corallines—Anatomy of the coral animal—Budding coral eggs—Watkins Glen.

THE geological formations of the Silurian age pass into those of the Devonian age by an easy transition. Yet the latter mark a new epoch in the evolution and progress of animal life, and thus stand apart as a distinct age in the history of geology. The Devonian age has been divided into the Lower and Upper Devonian. The first was when the great limestone formations occurred, while the rocks of the second period were mostly sandstone.

It is not probable that any marked change occurred in the configuration or aspect of the land and the condition of the air at the beginning of the Lower Devonian age. The transition from the preceding age was extremely slow, as are all steps in the geological history of the earth. As time passed away, however, the land changed both in character and extent. The coast-lines extended on both sides of the great bow-shaped uplift, the shallow adjacent seas gradually grew more shallow and were filled up by the washing down of sand and mud from the summits of the Laurentian Hills. But still a great part of the dry land as we now see it lay under water, and the sea for a considerable extent was of a moderate depth.

The earlier forms of animal life were slowly passing away, although types of each were still to be seen. No sudden or abrupt disappearance of any species occurred, but a change to higher and more complete organisms took place, and in the nature of events the older forms were displaced by the more recent.

In the Devonian age a new form of life appeared upon the earth—namely, the **Vertebrates.**

This order of animals, so entirely unlike and distinct from any that had appeared before, had a special feature characteristic of themselves, which gave them their distinctive name. This was the *spinal column* or *backbone.*

It was a bony, flexible spine composed of a number of separate pieces or *vertebræ* located longitudinally in the interior of the body of the animal. It was a new departure in the law of evolution, and pointed to a higher and more important order of animals—an order which in the course of time included fishes, reptiles, birds, mammals, and finally—man.

The earliest form of the vertebrates was the **Fishes,** and as they first appeared in the Devonian age, it has well been called the Age of Fishes.

These early Devonian fishes were of a different type from those of a later age. The vertebral column possessed a certain degree of mobility, the vertebræ themselves having more of the characters of the mammalia;

that is, they were vertebræ with the ball-and-socket joint, and flat intervertebral facets, instead of the inverted-cone vertebræ so characteristic of modern fishes.

The flexible spinal columns of these ancient fishes foreshadowed the reptiles, birds, and mammals that appeared later in the evolution of animal life.

The true fishes, with the vertebral column largely composed of cartilage instead of bone, and the vertebræ arranged like inverted cones, the apex of one fitting into the hollow base of the other, are the evolution of a later epoch.

This cone-like arrangement and cartilaginous structure of the vertebræ is a special feature of the fishes of the present period. Modern fishes have no lateral movement of the head upon the trunk. Their bodies are covered generally with thin overlapping scales, and their vertebræ are usually composed of cartilage instead of bone.

The Devonian fishes, especially the later ones, that attained a great size, had bony vertebræ, and large armour-like heads, with a more or less free movement on the trunk. This was a feature more like the reptiles than the fishes. Their scales were thick and large, and had the appearance as well as the effect of a coat of mail. Their vertebræ were bony and distinct, and ended in the upper lobe of the tail, which was a peculiar anatomical trait of those ancient fishes. No modern fish except the **Shark** has a tail formed in this way. The tails of those ancient fishes which have the spinal column end in the upper lobe have been called *heterocercal* tails. This is a special anatomical feature of the ancient fossil fishes.

In the tails of modern fishes there are usually two lobes of equal size, an upper and a lower lobe formed by cartilaginous or bony rays, and articulated to the end of the spinal column, but not a part of it. These have been called *homocercal* tails.

In Fig. 15 we have some of the earlier forms of fossil fishes. In Fig. 16 we have still other forms, and in each we see the peculiarly formed heterocercal tail.

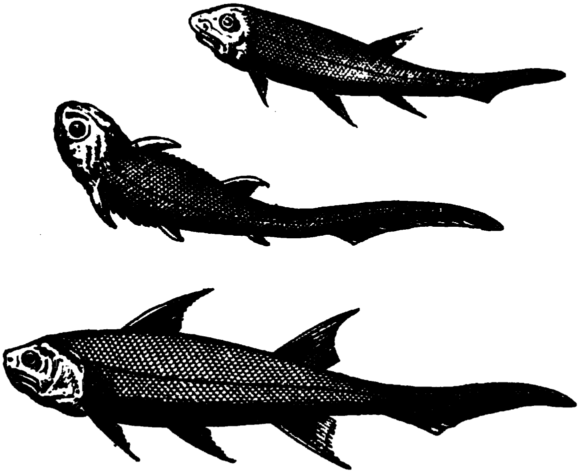


FIG. 15.—FOSSIL FISHES WITH HETEROCERCAL TAILS.

The evolution of the vertebrates—a form of animal life so dissimilar from anything that had appeared before, and so far in advance of it in point of structure—demands a special study into the anatomical and physiological changes that led to its development.

We have seen that the primitive cell, composed of protoplasm, organized in the course of time a covering for itself, a thin envelope or membrane, which has been called the cell-membrane.

This cell-membrane very soon became a very important structure. The vibratile cilia, which formed on the simple cell and on the groups of cells, like the olynthus, were prolongations of this cell-membrane, delicate processes that served to propel the tiny creature through the water in search of food.

The cilia and tentacles of other animals, like the coral polyp, are developed from this cell-membrane.

The early forms of animal life owe their diversity of structure and development into newer forms to changes in the growth and nutrition of this cell-membrane.

As physiological development advanced and animals were propagated by budding and by the formation of eggs, the cell-membrane played a still more important part.

In the egg, from which all vertebrates are *now* propagated, this membrane underwent important modifications in the production of the future animal.

This cell-membrane of the egg has received in modern times the name of **Blastoderm**, and during the process of embryonic development, whether this takes place while the egg is *outside* the body of the parent, or while the egg is *inside* the body of the parent, the changes that occur in the growth of the blastoderm lead to the formation of all the organs that enter into the complete structure of the body of the animal.

The blastoderm, whether it is the simple membrane that surrounds the delicate primitive cell, or a number of cells, in groups or masses, whether it belongs to the order of animals that develop entirely by external growth, or whether it is the enveloping membrane of the egg that develops either within or outside the body of the parent, is still the important structure that enters into the general formative element of tissues.

We have seen that the sea-worms were formed by a row of cells attached to each other like a string of beads, the union of the cells being marked by a slight depression, or circular furrow. The portion of the cell-membrane which came in contact with that of the next cell was absorbed, and this left a continuous tube, with an outside membrane marked by the circular depressions.

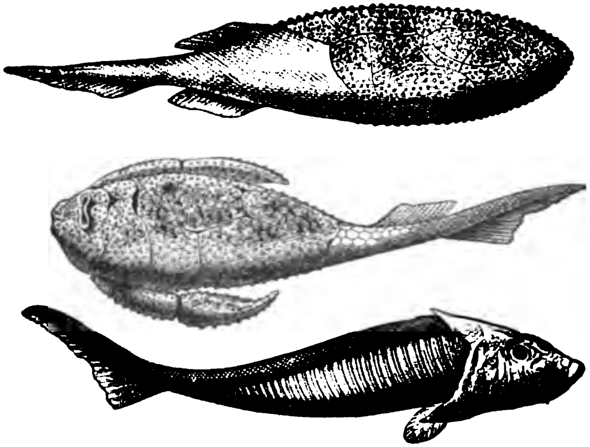


FIG. 16.—FOSSIL FISHES WITH HETEROCERCAL TAILS.

We have also seen that the stems of the earliest algæ or sea-weeds were formed in precisely the same manner; both animal life and plant life being originally formed by the same primary cells, and in the same simple manner. Later development caused a divergence into higher and more complex animals on one hand, and more intricate plants on the other.

The marine worm was compelled to seek its food in the sea, and in consequence it acquired a propulsive movement by an undulatory motion of its body. This caused a greater development of its external parts. The law of *use* has always been a powerful factor in the evolution of higher from lower forms of life, and it came early into activity in the progress of the marine worm from its simple to a higher plane of development.

The evolution of the primary fishes from the preceding lower form—namely, the marine worm, followed from necessity a simple and well-known physiological law of development and growth.

The delicate membrane which surrounded the body of the sea-worm, under the influence of the law of use and the more advanced needs of the animal, was thrown into a series of longitudinal *folds* or *ridges*, because in swimming the membrane was increased in thickness along the lines of greatest resistance, and corresponding furrows or depressions occurred along the lines of least resistance.

Two of these folds or ridges, running along the upper part of the body of the animal, or back, gradually increased in size and thickness, by a slow upward growth, and became what were afterwards called the dorsal plates, or neural arches.

These dorsal plates gradually approached each other along their entire length and upper border, until they coalesced and formed a closed canal running longitudinally along the back of the animal. This was the medullary canal, or the neural canal.

From the cells which lined this medullary canal was formed the medullary cord, or *spinal cord*, and at the larger extremity was formed the encephalon, or brain. At the same time the dorsal plates were forming, other folds or ridges formed on the sides of the animal, which increased in extent by the proliferation and growth of additional cells.

These side-folds soon assumed a double function. The inner or internal side developed into the cartilaginous framework or ribs, while the outer side formed the covering or scaly integument of the newly developed animal.

These side-folds have been called the ventral plates, or lateral folds, or abdominal arches, and from their growth and by their union along the median abdominal line they formed the cavity of the abdomen.

These processes were necessarily slow and gradual, but they finally transformed the sea-worm into a simple vertebrated fish, with a medullary canal and an abdominal cavity.

After a time a junction was formed of the dorsal plates or folds with the ventral plates or folds, and this junction produced in the *interior of the body* of the animal a slight thickening of the membrane running from one extremity to the other. This thickening produced a delicate cord-like structure.

This was the *chorda dorsalis*, the seat of development of the future vertebral column.

During the process of growth the chorda dorsalis showed slight transverse markings in its substance. These were the outlines of the future vertebræ. These markings increased in depth until they penetrated its entire extent, and the chorda dorsalis was thus subdivided into segments or pieces throughout its entire length. These pieces gradually developed into distinct vertebræ, but development progressed more rapidly in one end than in the other. In the end destined for the head the first changes took place, and development went on successively to the caudal extremity. These segments of the chorda dorsalis finally developed into the bodies of the bony vertebræ by the absorption of lime from the water and depositing it in the soft cartilaginous segments of the chorda dorsalis, until the whole series became a true vertebral column, or spine, composed of bone.

By a continuation of this same process of growth, and the gradual and more complete development of the various plates or folds, the different portions of the body are gradually constructed. The skeleton is formed and the scaly integument covering it. Increased cell-growth produces the first organs of special sense, the nerves and muscular tissues, as well as the earliest development of the organs of reproduction.

As development and growth progress, the tail acquires sufficient size and strength to act as an organ of locomotion. An intestinal canal also forms, consisting at first of a simple wide straight tube, running directly from the mouth to the anus. This is formed from the internal development of cells.

Afterwards a change takes place in the external form of the animal. Fins make their appearance by a process of budding or sprouting from the integument on the sides, back, and ventral aspect, and these serve as additional locomotory appendages.

A nutritious fluid, or blood, soon forms in the body of the new animal, and this is purified by small openings in the sides, to allow waste matters to pass outwards, and oxygen from the water to pass inwards, through a thin membrane by the process of endosmosis and exosmosis.

These small openings in the sides of the new animal —the fish—are the first development of those little feathery tufts called *Branchiæ* or *gills*, the organs for the purifying of the blood. They are replaced in the higher animals by *lungs*, or true air-breathing organs.

Thus the body of the new animal—the fish—is formed by the thickening and folding, in longitudinal plates or ridges, of the external cell membrane of the marine worm—a membrane which developes all the characters and powers of growth of the blastoderm.

The above changes in the evolution of the fish from the sea-worm result from the special activity of growth of particular parts of the cell-membrane. If this membrane were to simply increase everywhere at a uniform rate, it would become thicker, as well as more extensive, but without any special alteration of form, and this is actually what does happen in the early evolution and subsequent development of the trilobites and other forms of crustaceans. The external cell-membrane simply thickens at every point; and afterwards assumes its manifold shapes by the formation of transverse and longitudinal ridges, whose development is wholly confined to the outside of the body of the animal, the inside retaining the character of its soft parts, and developing the internal organs from an elaborate production of cells, without any tendency to the formation of bony tissue.

It will thus be readily understood that, during the progress of evolution and growth, the blastoderm or cell-membrane grows more rapidly at particular points and along certain lines than elsewhere.

It is impossible always to determine the cause of such a concentration of growth, but the result is that the blastoderm, enlarging with varying degrees of rapidity and in different directions, is thrown into a series of undulatory folds or ridges, which show by their position and size the unequal expansion of its mass. If it grow more rapidly at one point than at another, it will form at that spot either an eminence or depression, according as it meets with less resistance above or below. If a similar rapidity of growth should take place in a transverse direction, the result would be a fold or series of folds in a transverse direction. But if this rapid increase should take place in an antero-posterior direction, it would cause a longitudinal fold or series of folds or ridges.

The subsequent history of evolution and development shows continual repetitions of this process, and often on a much larger scale than is required for the development of our little primitive Devonian fish from a sea-worm.

The internal organs, the brain, heart, intestinal canal, the various glands, and mucous and serous membranes are all formed in a similar way.

They are at first smooth or straight; they then become convoluted or folded during the various stages of growth, especially when their growth is more rapid than the surrounding parts.

The cell-membrane or blastoderm of the lower animal organisms is at first apparently of uniform structure throughout. It presents an appearance of homogeneity of texture, and its uses seem sufficiently simple, yet certain and particular parts have from the very beginning a *physiological individuality* which leads to its subsequent growth and development into a special organ, or a part of an organ.

This is early evident from the method in which the local activity of growth, stimulated by nutrition, gives rise to the appearance of folds or ridges running in certain definite directions, and determining in this way the future location of the head, tail, and sides of the body of the animal.

Nutrition plays an exceedingly important part in the development and growth of organs. It determines largely the evolution of new forms of life, and the growth and propagation of those new forms.

We can now see very clearly how the little marine worm, in obedience to a law of physiological development, stimulated by the upward tendency of the force of evolution, and the higher needs of the animal, the more favorable surrounding conditions, as well as the law of use, was developed into a crustacean, and later into a simple fish.

In the crustacean, the external cell-membrane developed almost wholly upon the outer side. It was thrown into a series of transverse ridges, which by their growth became the shell or crust of the animal. This external development continued through a long series of animal forms, and we have the whole order of articulates and crustaceans as a result of this special growth. In this order of animals there was no tendency to the formation of bony tissues. The special tendency was to develop an outer or external resistant covering for the protection of the soft body of the animal, and this, as we have seen, was by a thickening and folding, and hardening of what was at first a delicate homogeneous membrane.

The variety of crustacean forms resulted from a more advanced development, and a more special need of the animal, continued amid favorable surroundings for a long period of time. A variation of external configuration in these animals results from a greater activity of growth in one direction than in another. In the fish the development of the external membrane soon led to a double function. The folds or ridges were longitudinal, and in the process of growth, as they closed upward along the dorsal median line to form the spinal canal, and as they closed downward along the ventral median line to form the abdominal cavity, they elaborated a special cell-growth, which formed an external scaly integument on one hand, and the various internal organs on the other. A tendency was also manifested for certain internal membranous structures—the chorda dorsalis—to absorb calcareous matters from the water, and elaborate them into bone, and in this way the bony vertebral column was finally formed.

It is more than probable that the *first fishes* were formed in vast numbers in the physiological manner above described. But as their development reached a higher stage, and a certain point in completeness, their further increase took place through the production and incubation of eggs, and this process has continued to our own time. When the production of the egg was finally established, the development of the young animal from it consisted of a series of changes in which the different organs make their appearance from modifications of that same membranous structure, the blastoderm. Some of these organs are temporary, and serve for the growth of the embryo, and later still for the early needs of the young animal during a certain period of its existence, while others assume a more permanent structure and character, and, after passing through various alterations of form and size, become finally component parts of the adult organism.

We shall see in a subsequent chapter that changes occur in a later age in the organs of locomotion of the fish, when limbs are destined to replace the tail, and a time at last arrives when the tail altogether disappears, or remains only as an atrophied or rudimentary organ, while the limbs as new locomotory appendages become fully developed, and a new form of animal life comes upon the scene. Changes also occur when the gills are replaced by lungs, and the animal heretofore confined to an aquatic mode of life becomes capable of living on land as an air-breathing animal.

The fossil remains of these early fishes have come down to us, telling us the story of their lives in indestructible stone. We see the delicate foldings and ridges and plates, as well as the more perfectly developed bones, and the naturalist sees in these parts the whole history of the evolution of the animal from its simple primitive form to its more complete organization as a vertebrated animal.

From these early and simple fishes were evolved others of a more complex structure and of greater size. In Figs. 15 and 16 we see the various forms whose fossil remains have been so well preserved to us. In Fig. 16, No. 2, we see the species known as **Pterichthys,** with wing-like fins, and in this animal, which is already, in the Devonian age, half fish and half reptile, we see very clearly the foreshadowing of the true reptiles, and the wing-like fins that mark such animals as the penguins and steamer-ducks of the present age. In the Straits of Magellan, that narrow and tortuous strip of water that divides Terra del Fuego from the mainland of Patagonia, I have seen on the sandy beaches and shelving rocks great numbers of sea-lions, penguins, and a peculiar diving bird, called "steamer-duck" *(Anas brachyptera)*, all living together in the most perfect harmony, although so dissimilar in form and appearance.

There is a most remarkable similarity between the anterior flippers of the sea-lions, the scaly membranous fin-like wings of the penguin, and the fin-like and naked wings of the steamer-duck. They are all air-breathing animals, but are aquatic in their habits, and are exceedingly expert swimmers and divers. Their motion on land is labored and awkward, but graceful in the water, and they can dive rapidly, and swim for long distances beneath its surface before rising to breathe. In each of these animals the anterior limb is a fin-like paddle, and is used solely as an organ of propulsion in the water. Neither the penguin nor the steamer-duck have the least power of aërial flight. It has been said that the penguin sometimes uses its paddle-like wings to aid it in walking on land, like a quadruped "on all fours," but I have never observed this, although I have watched them closely. In each of these animals the radius and ulna, and the carpal bones, are more or less consolidated, and with the metacarpals and phalanges are concealed in a thick, webbed, scaly integument, which gives them the character of a fin or paddle. In the pterichthys, as shown in Fig. 16, No. 2, we see a wing-like fin, and in a later age we see the same kind of fin in the **Plesiosaurus**, a species of reptile that flourished so greatly in the age of reptiles. It would seem that the same kind of limb—the fin-like paddle—had been transmitted from those past geological ages to our own time, and this peculiar form of fin-like structure is a partial development in the first instance, and an arrest of development at that special point, and along that special line of animal evolution.

In Fig. 16, No. 3, we have what seems a strange form to us, the **Cephalaspis**, a fish with a large movable head, strong spinal column, and thick ribs. This

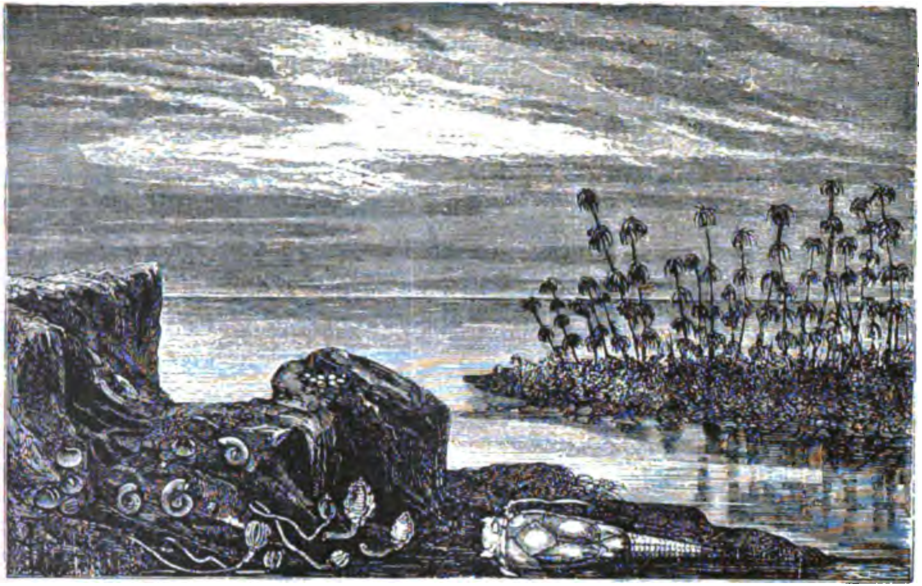


FIG. 17.—IDEAL VIEW IN THE DEVONIAN AGE.

animal is quite reptilian in character, and points clearly to the true reptiles that appeared in a succeeding age.

All these six varieties of Devonian fishes shown in Figs. 15 and 16 are doubtless derived from one. The differences in size and form are due to a more elaborate and more perfect development and growth, continued through great periods of time.

Another fish of the Devonian age was the **Gar-pike,** a long, slender-bodied fish, with powerful jaws and teeth, and the armor-like scales so characteristic of the ancient fishes.

This species is preserved to our own time. One of the most interesting varieties is found in large numbers in the warm seas near the island of St. Helena. I have seen them sporting in the waters near that island, and they still retain the jaws and teeth and the shining scales of their remote ancestors. They are fearless and predatory as their remote prototypes undoubtedly were. While in an open boat near the shore, I have placed a piece of wood on the surface of the water, and as soon as they saw it they would approach close to it, leap over it, and swim round to repeat the same manœuvre over and over again.

They reach a length of from eight to fourteen inches, and are very plentiful in tropical seas.

The plan of construction of these varieties of Devonian fishes is practically the same. In each the distinguishing feature—the vertebral column—is fashioned upon the same model—constructed upon the same pattern. There is a variation of detail, but the tendency is to assume a greater degree of development in point of structure and size.

The landscape of the Devonian period showed a tendency to a greater development of plant life. In

Fig. 17 we have an ideal view of the land and the plants then in existence.

It will be seen that the plants were still of a simple character, and the varieties were few in number. The early algæ or sea-weeds, which were first formed by a row of single cells, and grew by attaching themselves to rocks in the bed of the sea, were of a very simple and lowly character. They developed slowly by the process of growth, and gradually assumed higher capabilities and a more elaborate development. Their early increase was due to budding, and as the sea grew more shallow, and the detritus of erosion was spread out on its floor, it formed a more favorable habitat for the increase of plant life.

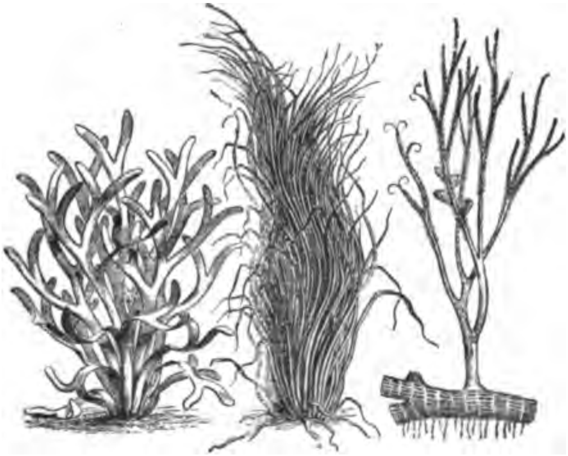


FIG. 18.—EARLY AQUATIC PLANTS.

In Fig. 18 we see three forms of these simple early aquatic plants, but there is a strong tendency, even thus early in the history of plant life, to develop into a higher and more complex growth.

In all these forms we can see plainly outlined the land plants that appeared at a subsequent epoch. The crinoids also increased in size and complexity.

In Fig. 19 we see one of these beautiful crinoids or stone-lilies, and we notice a considerable advance in intricacy of structure.

In this variety of crinoid animal the diverging rays or branches plainly foreshadow the *plant*. Animal life at this period runs side by side with plant life.

The crinoids form an interesting group, for on one hand they point to plant life, and on the other to a greater variety of animal forms. The varying shapes they assumed in the successive geological periods are particularly instructive. These older crinoids combined characters that foreshadowed the advent of the true star-fishes and the sea-urchins of the type of the radiates; and so prominently were their prophetic characters developed that they are frequently mistaken for star-fishes and sea-urchins.

They gradually dwindled in number and variety until they are at present represented only by the **Pentacrinus** and the comatula which are found near Porto Rico in the West Indies.

The modern pentacrinus closely resembles the ancient crinoids (Fig. 19).

The comatulas are more delicate in structure, a modern variety being found on our own coast near South Carolina. Its peculiar radiate character is well shown in our museums.

This animal is sometimes called the **Feather-star,** from its fancied resemblance to a feather. On one side of the arms are little beards or rays which give to it the appearance of a feather; on the other is the tough skin or integument, and in the centre of the disk are the mouth and anus.

The comatula has a stem only in the early stages of its growth. As development advances it drops from the stem, and throughout adult life it leads a free and independent existence, roving about at will in the shallow seas that bathe our coasts.

It has been stated that in the early or Lower Devonian age, some of the great limestone formations of the earth had their origin. These extensive limestones were largely composed of the reefs formed by the little animals known as reef-building corals. It is a well-known fact that the *true reef builders* cannot exist in the present age except in warm tropical seas and in waters of moderate depth. A temperature of from 68 ° to 86 ° F. is required, and a mean depth of about fifteen fathoms, or ninety feet, must not be exceeded. Below that depth the waters are too cold for the delicate reef-building coral animals to grow. These warm seas and favorable conditions prevailed in the Lower

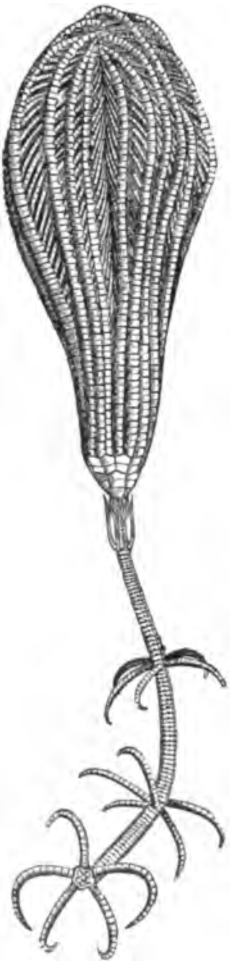


FIG. 19.

CRINOID OR STONE-LILY.

Devonian age—a uniformly warm temperature and a shallow sea. As the water held in solution large quantities of lime, the conditions were exceedingly favorable for the growth of the coral animal and the formation of extensive coral reefs, hence the great extent of these reefs in the early Devonian age. The true reef-building corals are of several varieties, and of different forms, living at different depths of the water. Those that live at the lowest depths and build the foundations of the reefs are called **Astræans,** or **Star-shaped Corals.** They build up the reefs from the lowest depths at which they can flourish, about ninety feet, to within about six feet of the surface. Here the pressure of the water becomes less, and their activity ceases. But they give place to a new variety of animal, the **Meandrinas** or **Brain Corals,** and the **Porites,** who continue the work of constructing these vast and massive reefs to nearly the surface of the water. These also have their bounds within the sea.

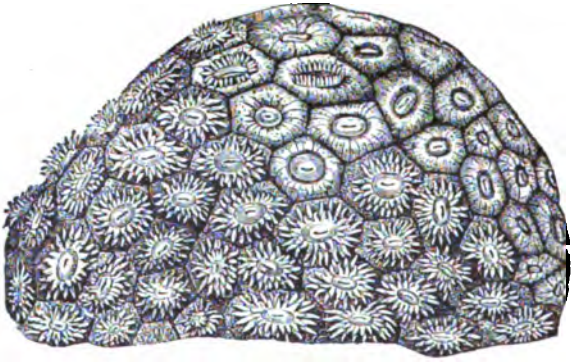


FIG. 20.—ASTRÆAN OR STAR-SHAPED CORAL (FAVIA PALLIDA).

They in their turn reach the limit beyond which they are forbidden by the laws of their nature to pass, and at that point they must pause. The coral wall, however, continues its steady progress and growth, for here another variety of animal comes into activity, the **Madrepores** and the **Millepores,** besides a variety of **Sea-fans** and **Corallines.**

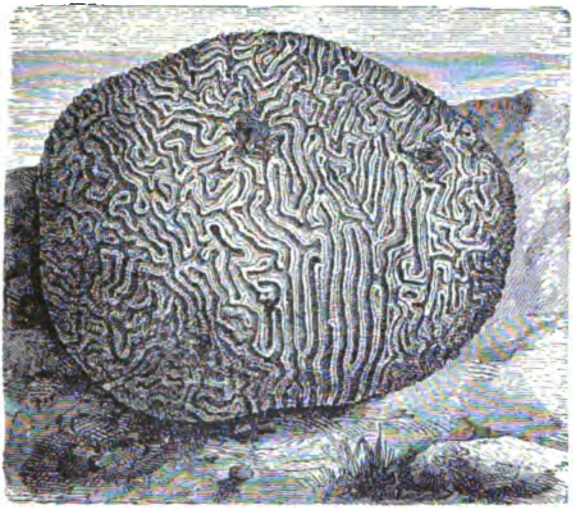


FIG. 21.—MEANDRINA OR BRAIN CORAL (DIPLORIA CEREBREFORMIS).

These important coral-reef-building animals, the astræans, the meandrinas, the madrepores, and the millepores are well shown in Figs. 20, 21, 22, 23.

They are the little creatures whose delicate bodies have turned into stone and formed the immense and solid reefs so extensively seen over vast areas of the surface of the earth.

The coral animals belong to the order of radiates. Their radiate structure is preserved throughout all the varieties. The minute anatomy and the internal structure of these animals are very interesting. The soft body is composed of a mass of cells, and is of a more or less cylindrical shape. The body is divided by vertical septa or partitions from top to base, leaving open spaces or chambers between. In the centre is an open space, the digestive cavity, which connects by an opening at the base with all the chambers. At the top is an aperture which serves for a mouth, and around this is a wreath of hollow tentacles, each one of which connects at its base with one of the chambers, so that all parts of the animal freely communicate with each other. This little creature has the power to absorb and assimilate for its own use matters in the water about it, and it possesses a remarkable energy in absorbing lime from the sea water in which it lives.

The coral animal reaches maturity soon after birth, and then at once establishes itself on a firm foundation where the depth of the water is suited to its needs. Here a double function immediately springs into activity—namely, propagation, and the absorption of lime. Very soon it begins to absorb lime from the sea water and deposit it in the soft walls of its body, and in time the whole body becomes as hard as stone, except the stomach and the wreath of wavy tentacles about its upper border. When the body has turned to stone the stomach decomposes, and the tentacles drop off and disappear. The animal is now dead, but his hard stony body becomes a permanent part of the coral reef upon which it grew.

As soon as the little coral animal *first* attaches itself solidly to the ground of the sea bed, and before it begins to absorb lime, it begins to bud from the top of its body, from its base and sides, until it is surrounded by a number of tiny individuals like itself. These in their turn begin to bud, surrounding themselves with a numerous progeny, but all remain attached to the parent coral. In this way the community increases by millions.

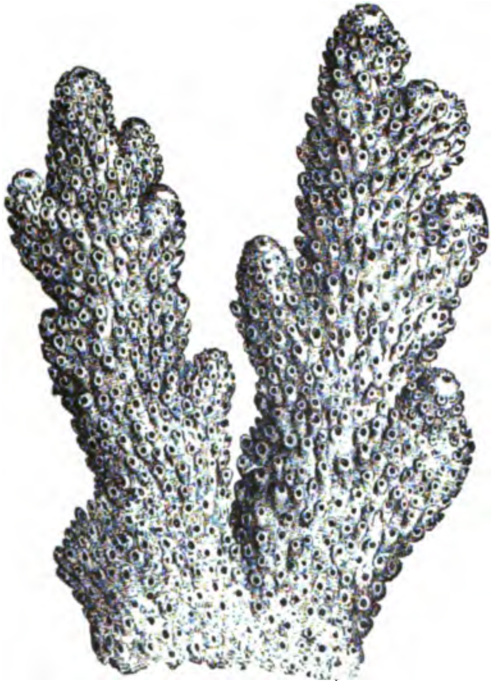


FIG. 22.—MADREPORE CORAL (MADREPORA PLANTAGINEA).

Besides the process of budding, the coral animal increases by giving birth to eggs. These eggs are formed in the body of the animal, and are carried in great numbers on the inner edges of the partition walls. It is probable that these eggs are formed by a process of budding of the partition walls *inside* the animal, as the buds proper form on the *outside* of the body of the animal.

The eggs, however, soon become detached from the partition walls and drop into the sea, where they float about as little soft, transparent, pear-shaped bodies or cells, with an exceedingly delicate and thin cell-membrane.

This cell-membrane soon pushes out little fine prolongations of itself which develop into cilia, and by the rapid motion of these the egg, or cell, is able to swim about freely in the sea. The special activity or blastodermic character of this cell-membrane is early manifested.

By and by they find a congenial spot on which to establish themselves when they become attached to the ground by a part of their cilia. This becomes the base. The rest of the cilia, no longer needed, drop off. A depression takes place in the upper part, which gradually deepens to form a mouth and inner cavity, while the upper edge expands into points to form the tentacles. The productive life of the new animal then begins. It buds at every part on the outside to form new individuals, while eggs are produced on the inside to increase the new community. It then absorbs lime and deposits it in the soft tissues of its body until at last it turns to stone and dies.

Both buds and eggs are produced by millions by the parent coral animal, which in their turn produce millions more, and in this manner the solid coral reefs are permanently built up, and in the course of time assume the vast dimensions that we now see.

The astræans, the meandrinas, the madrepores, the millepores, and the sea-fans are all varieties of the coral animal. While some can only live and flourish at the lowest coral building point, namely, at about fifteen fathoms, others delight in more shallow seas, but all pursue nearly the same method of propagation and growth, and all finally change to stony hardness and death, and become a permanent part of the coral reef. The beautiful forms of coral shown in Figs. 20 to 23, and seen in some of our noble museums, are the labor of the delicate little coral animal carried on either in the deeper quiet seas, or near the surface, amid the ceaseless roar of the restless surf.

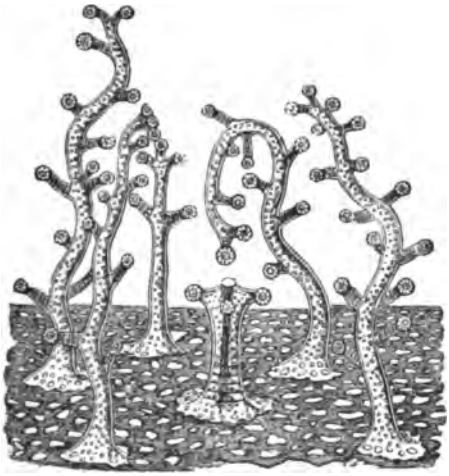


FIG. 23.—MILLEPORE CORAL (MILLEPORA).

The varieties in form of corals are due to a variety in shape of the body of the animal, some producing the astræans, others the meandrinas, the madrepores, or the millepores. The ancient Devonian coral reefs were formed by the same kind of coral-building animals as those now found in the tropical waters of the Pacific Ocean.

An excellent display of the old fossil coral reef of the Devonian age is found at the falls of the Ohio River near Louisville, Ky. When that locality formed the southerly border of the bow-shaped primary uplift of land in the Azoic period, and was washed by the waters of that ancient sea, these little coral animals built up that extensive reef in the manner we have described, and left it as a permanent record of their long and patient labor.

If we compare the olynthus with the sea-anemone, the coral-polyp, and the crinoid, we shall see a striking similarity of structure and form among them. Each was a mass of individual cells, of the same character and composition. Each assumed a special activity, a physiological individuality, and a peculiar power in the cells for each to do a particular thing. One group (the olynthus) by virtue of this special activity, developed into the sponge, another group developed into the sea-lily, another into the sea-anemone, and still another into the coral-polyp.

Each followed the same pattern, the type of the radiate, and while a divergence of species and of function ensued, the radiate type was preserved among them all. A still further modification of form ensued in the star-fishes and the echinoderms.

From a simple origin and a homogeneity of composition these varying animal forms, through the influence of the cells having an aptitude to do a certain *special labor*, were evolved.

The Devonian age saw the evolution of fishes, of coral-building animals and of a lowly organized species of land plant. It was an age of vast length, for the evolution of a vertebrated fish from an invertebrated sea-worm required a long period of time. The final development of the great predatory shark-like fishes,

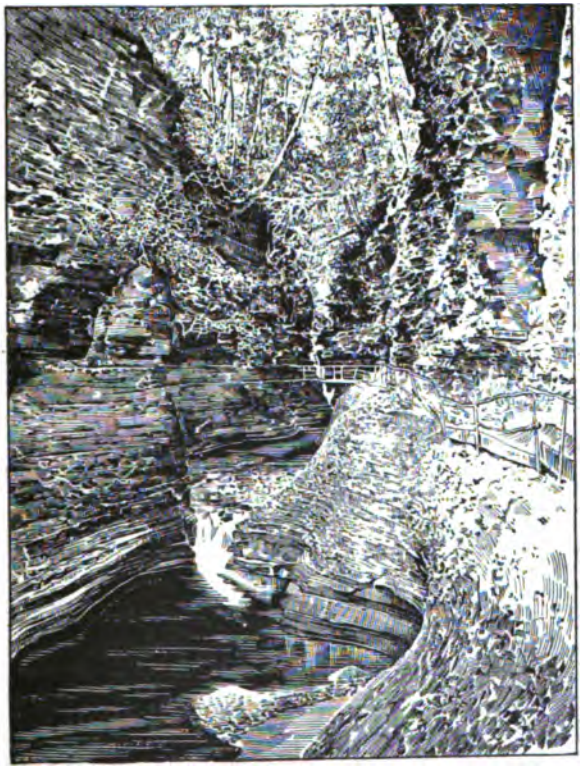


FIG. 24.—SANDSTONE FORMATIONS OF THE UPPER DEVONIAN PERIOD, WATKINS GLEN, N. Y.

from the earlier forms, was a slow and gradual process, and required long ages for its accomplishment.

The formation of the immense coral reefs in the lower Devonian age, by the slow and patient labor of so many myriads of coral-polyps, required enormous lapses of time. Those vast solid coral reefs grew through the patient labor of countless ages. The sandstone formations of the upper Devonian age also required countless ages. A good idea of the great length of this period may be formed by examining a deep chasm in the sandstone rocks near Ithaca in New York State, known as Watkins Glen.

In Fig. 24 we see a chasm varying in depth from one hundred to one hundred and fifty feet, which has been cut through the solid sandstone rock by the eroding action of running water. The sandstone through which this deep chasm passes was originally eroded by rain falling upon the higher levels of the Laurentian Hills, washing them down as fine sandy materials, and spreading them out on the floor of the sea, where they attained a thickness in some places of two hundred feet. This gradually hardened into a bed of firm sandstone. Later this bed was raised above the sea by an uplift, and became dry land. The rains ran over its surface, and by slow degrees wore away a channel nearly along its central part. This slowly deepened and widened until it formed the curiously carved and tortuous chasm as we now see it. When we realize how exceedingly slow these different processes were, we can gain a clear idea of the prodigious length of time required to complete a labor of such stupendous magnitude.

When the Devonian age closed—an age whose progress must be marked by the flight of millions of ages, the earth had made vast strides towards becoming the fitting habitat of a higher grade of both animal and plant life.

One great step had been taken in the upward path of progress—namely, the evolution of the vertebrates.

Having once established this great order of the vertebrates by the simple and now well understood physiological law of evolution, all of the rest of the order follows regularly and sequentially upon the same general plan.

This physiological law of evolution, development, and growth was the result of an ever upward tendency in the animal scale, and the activity of special parts and special organs to do a special thing, stimulated by an abundant nutrition in a congenial habitat.

CHAPTER V.

THE PALEOZOIC AGE:—THE CARBONIFEROUS PERIOD. AGE OF COAL PLANTS AND OF EARLY REPTILES.

Subdivisions of the Carboniferous period—Formation of islands—Shallow seas—Sharks—Lowly plants—Marshes—Increase of land areas—Deposits of coal—Great forests; their uses—Mollusks—Wave-marks—Footprints of Sauropus primævus—Fossil saurian bones.

AT the close of the long Devonian age, we find the terrestrial landscape somewhat changed. Extensive and widespreading marshes stretched away in vast distances in a monotonous level. The shallow sea was dotted with numerous islands and covered a considerable portion of the still submerged continents. The land was increased in extent by these islands—an archipelago of newly uplifted isles, which were scattered here and there over a widespread area, and also by the filling up of the superficial seas, adjacent to the coast line, by the erosion and washing down of the higher summits of the hills through the influence of long-continued rains.

The sea was largely tenanted by shark-like and predatory fishes. Many of them were of great size, and of a shape at present unknown. The coral animals too made the seas still more shallow by the building up of extensive coral reefs. The vegetation was still simple in character, but it was destined to be soon replaced by a higher order of plant growth that was about to spring into activity.

Geologists have divided the Carboniferous age into three periods, as follows:

1. Subcarboniferous.
2. Carboniferous.
3. Permian.

An earlier and a later Carboniferous epoch is a convenient designation in treating of the changes that occurred in the land and the increase of terrestrial vegetation. There was a marked increase in the extent of dry land. The still submerged southern part of the continent underwent many changes. Points here and there were raised above the sea-level, forming numerous islands, with more or less shallow intervening waters, which were destined later to become marshes, and afterwards dry land. This formation of extensive marshes had an important influence in the evolution of reptilian forms of life. Here we see the influence exerted upon the evolution of animal life by the formation of extensive tracts of marshy land. A fish is slowly transmuted to a reptile.

The earth thus far in its zoölogical history was the *habitat* of marine animals only. All of them—the worms, sponges, mollusks, polyps, radiates, articulates, and the vertebrates were denizens of the sea. The few plants that existed were algæ or sea-weeds, except a few lowly forms of shrub-like plants that grew out of the rocks near the waters.

These early plants were of cell-origin, and very soon set out on a line that separated itself and diverged from the line that marked the development of animal life.

As in animal life the *cell* assumed a tendency to do a certain special kind of labor, to become a living organism with an ultimate independent mode of existence and migratory habits, so in plant life the *cell* assumed a tendency to do a certain special kind of labor, and to become a living organism with a fixed and nearly stationary mode of existence.

In the cell that developed into animal life there sprang into activity a vitality, accompanied by *sensation* and *motion*. In the cell that developed into plant life, vitality sprang into existence, but without either sensation or motion.

The animal cell manifested a tendency, through certain changes in its cell-membrane, to elaborate organs of special sense and organs specially adapted for locomotion. The plant cell manifested a tendency, through certain changes in its cell-membrane of a different character, to elaborate ligneous fibre and foliage, which were to act as special organs of growth.

The hosts of marine animals found sufficient food in the sea for their nourishment. They preyed largely upon each other besides. As plant life increased in complexity and variety, and became fit to nourish animal life, a *new form* of animal life was possible, and it appeared later. Higher plant life influenced the development of higher animal life. Plant life in the Carboniferous age found a congenial *habitat*, and it increased rapidly under the favoring conditions then existing. The numerous low islands and the shallow seas of fresh water gave abundant ground upon which plants could grow. The washing down of sand and mud still further increased the extent of the ground. The uniformly warm atmosphere, the sunlight, and the copious rains produced conditions that were exceedingly favorable to the rapid growth of vegetable life.

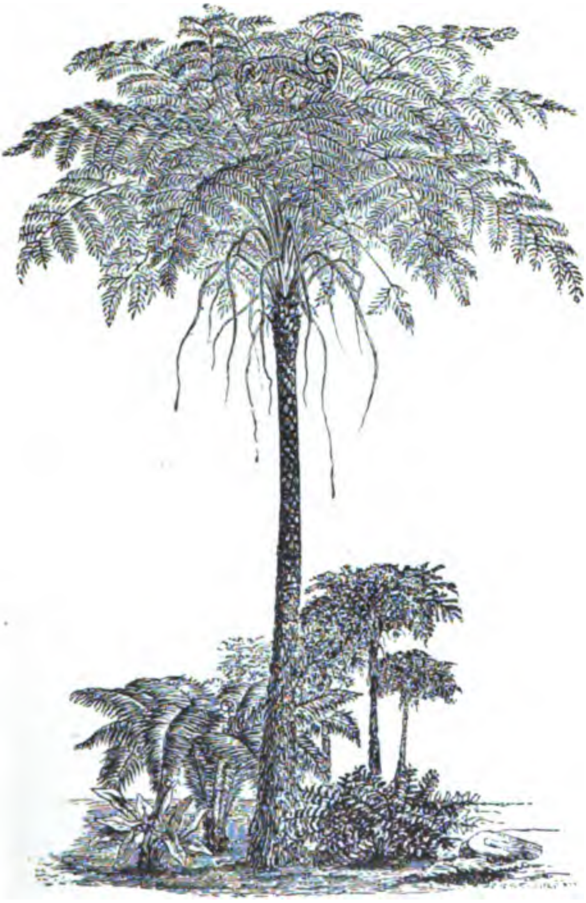


FIG. 25.—TREE FERN OF THE CARBONIFEROUS AGE.

We find the vegetation of that age of a light cellular character, of the kind to grow and mature rapidly, and not of the hard, solid, compact character of most of the trees of our own time.

FIG. 26.—MODERN PALM.

The Carboniferous forests rejoiced in trees of a peculiar light porous or cellular kind. In Fig. 25 we see a beautiful form of tree fern, which grew abundantly at that time and flourished in vast numbers.

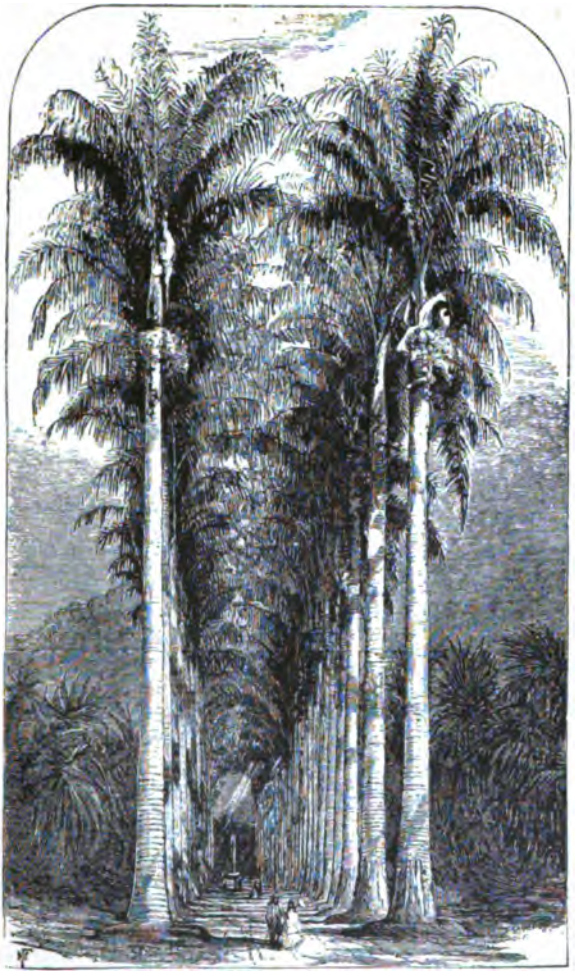


FIG. 27.—ALLEY OF PALMS, BOTANICAL GARDEN, RIO DE JANEIRO.

The peculiar graceful, palm-like character of these ancient tree ferns is worthy of notice. In many of the modern palms of Brazil we see a close resemblance to these ancient types.

By way of comparison, I have given in Figs. 26 and 27 two forms of palm I saw many times and in great numbers in Brazil.

That in Fig. 26, the Fan Baccaba, I have seen growing in Pará, along the banks of the Amazon River, and as far south as Pernambuco. While it is a true palm, and differs in many important respects from the ancient tree ferns, it has many characters in common with them.

The palm shown in Fig. 27 is the Oreodoxa Oleracea, and the cut represents a view of the Alley of Palms in the celebrated Botanical Gardens of Rio de Janeiro.

These graceful and beautiful palms rise to a height of eighty feet, the dense green tufty tops meeting in a thick arch overhead, and springing from a smooth trunk as straight as an arrow. I have never seen in any part of the tropical world so wonderful a display of palms as exist in this famous garden.

Another form of palm which I saw in Brazil is the solitary and rather rare, but very beautiful, Cocoeiro palm. This rises in a heavy straight stem to a height of more than eighty feet, and is surmounted by a tuft of broad green branches, which give it an exceedingly graceful and majestic appearance. This superb palm gives a beauty and a dignity to the landscape which we can hardly appreciate in our temperate zone. It is well shown in Fig. 28.

Among modern palms the most important and characteristic are the cocoa-nut palm *(Cocoa nucifera)*, the sago palm *(Sagus Rumphii)*, and the date-palm *(Phœnix dactylifera)*. A species of palm, the palmetto,

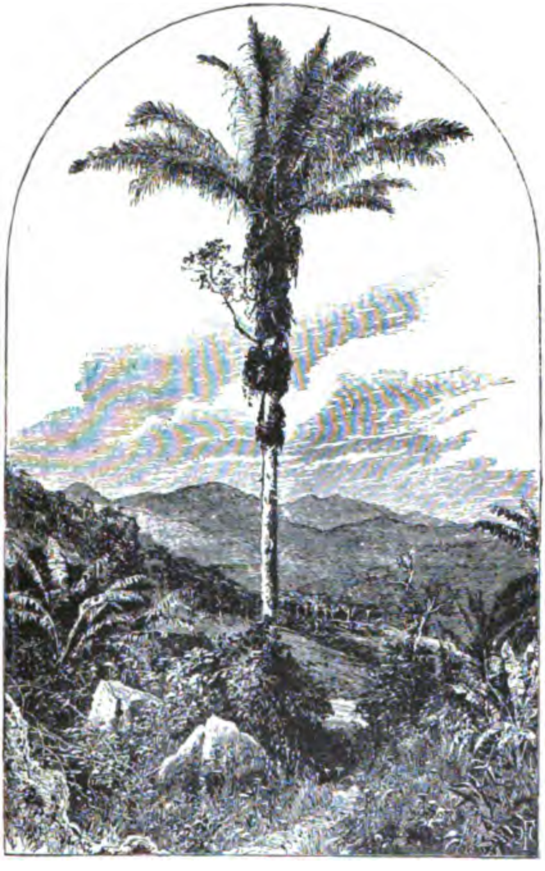


FIG. 28.—COCOEIRO PALM.

grows in our own country from South Carolina to Florida, and with this exception all the others are natives of the torrid zone.

None of the ancient trees of the Carboniferous age produced fruits, while their modern successors, the palms, are many of them fruit-bearing. Thus the date-palm of Fezzan and Barbary furnish the native tribes with a large part of their daily sustenance. The sweet and nutritious fruit—the date—is dried, and with a bag of these, and a skin of water, the native sets out on a long journey across the sandy and burning deserts, and feeds alike himself, his camel, his horse, and his dog for many days, with no other form of food.

The cocoa-nut palm is perhaps the most useful tree in the world. Its wood, which is called porcupine wood, is susceptible of a high polish. The tough fibres of the outer covering of the fruit are made into mats and floor-matting, cordage and brushes. The shell of the nut makes convenient bowls and dippers. The milk contained in the nut is sweet and delicious, while the kernel, when it is in a soft and albuminous state, is agreeable and wholesome. A sweet and pleasant sap flows freely from the wounded spadix, as much as a quart a day for two or three months, and this when partially evaporated by boiling yields a very good sugar. The fermented sap makes a wine, and, if distilled, yields a sort of spirit, called arrack. The leaves make thatch for dwellings, and are made into hats, baskets and even paper. Fences and houses are built from its wood, and the ashes yield potash.

Among the ancient trees flourished also the calamites, which so strongly resemble our modern fir and spruce.

Another variety which closely resembled the calamites was the sphenophyllum (Fig. 30).

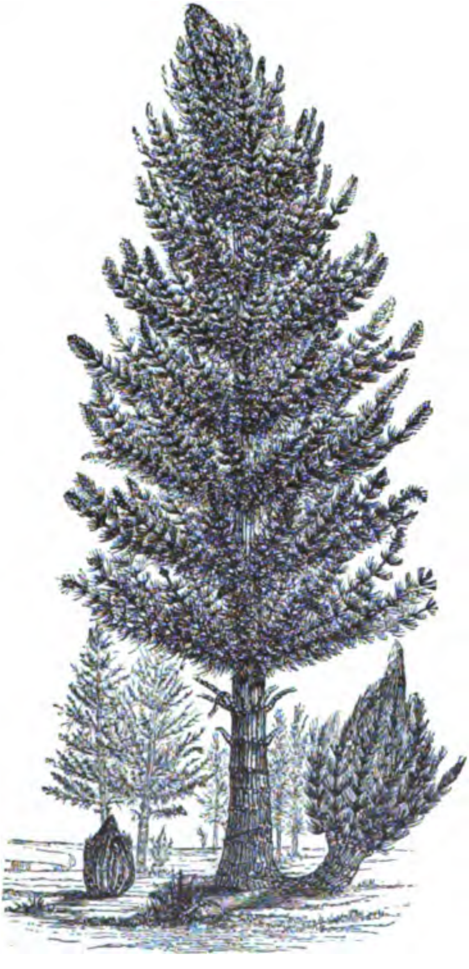


FIG. 29.—CALAMITE.

The lepidodendrons grew in great numbers in those early Carboniferous forests, and were quite unlike any of the modern forest trees with which our eyes are familiar.

In that age a tree closely resembling our modern palms lived and flourished luxuriantly.

In the ideal view of a Carboniferous forest of the coal period we see several varieties of these great forms of plant life as they must have appeared in that remote age.

All these ancient trees grew rapidly under the combined influences of torrid heat, strong sunlight, and copious rains.

It was an instance of an enormous increase of cell-growth in plants under the favorable conditions of soil, of sunlight, of heat, and abundant moisture.

Besides these trees of great size there were many low fern-like shrubs that completed, as it were, the forest landscape.

The immense forest growths of the Carboniferous age had a threefold influence.

First, they cleared the atmosphere of any remaining traces of carbonic-acid gas, for after a certain portion of this gas had been absorbed by the waters of the sea there still remained in the atmosphere a considerable quantity that was incapable of such absorption. This was elaborated into plant tissue through the influence and agency of plant foliage. The leaves of plants have the power of absorbing this gas, which is unfit for respiration, and storing it up in their tissues. In this way the atmosphere is rendered clearer and purer, and the deleterious gas is made to act as another element of growth upon plant tissues.

Secondly, these great forests with their lesser vegetation became, through a peculiar chemical influence, the

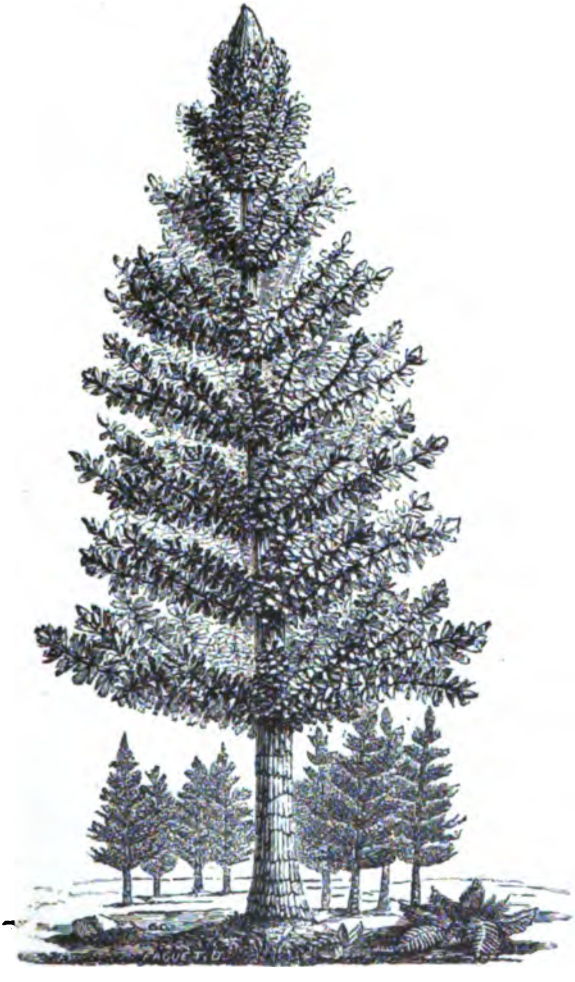


FIG. 80.—SPHENOPHYLLUM.

vast beds of coal that are now so indispensable to the industries and civilizations of the world. These forest trees grew, matured, and fell, to give way to new and successive growths, and so on during vast lapses of time. Great masses of these tree-trunks and shrubs, which were the slow growth and accumulations of ages, were buried and became changed in their character. They lost some of their ligneous constituents and were transformed into carbon by the slow decomposition of organic matter and the development of tarry or bituminous substances. It was a chemical process by which the vegetation became mineralized through partial decomposition and slow imperfect combustion.

Thirdly, this abundant vegetation made possible a higher form of animal life, by furnishing a plentiful and nutritious food to such animal life when it appeared. Hitherto animal life was wholly aquatic and subsisted on food found in the sea. If no vegetation had ever appeared on the land, if the rocks had always remained naked and barren, marine life would have continued and terrestial life had remained unknown. The Carboniferous age made future land animals possible, by furnishing them with an abundant food in their tender twigs and foliage. Grasses, if any existed at this time, were probably coarse marsh reeds and marshy tufts of water plants. Another factor in the evolution of reptilian life was the formation of extensive marshes during this age.

These marshes were formed, first, by the slow and gradual uplift of the land to within a few inches of the surface of the sea; second, by the filling up of the shallow seas by the washing down of sand and mud from the land; and, third, by the decomposition of immense quantities of vegetable matter that grew out

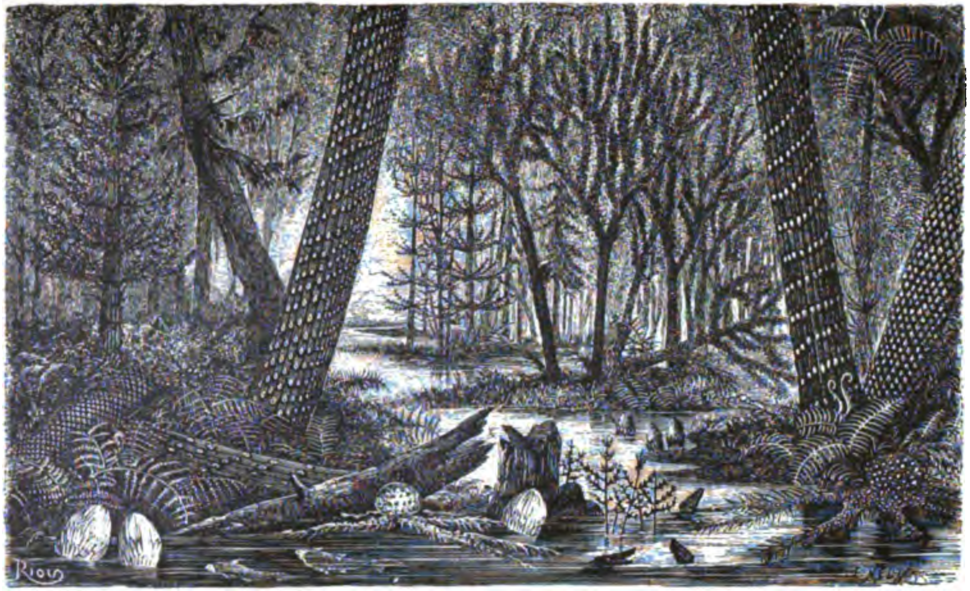


FIG. 81.—IDEAL VIEW OF A CARBONIFEROUS FOREST.

of and fell into these shallow seas and turned to marshy vegetable mould.

We see this same process going on under our eyes today; it went on, on a vast scale, in those remote Carboniferous ages.

Those ancient marshes of wide extent partially caused a change in animal forms from the fish to the reptile which we shall fully study in the succeeding chapter. The marshes were a prominent factor in causing a change of anatomical structure in the fishes and early reptiles.

The third division of the Carboniferous age, the Permian, was a continuation of the first two—the Subcarboniferous and the Carboniferous. This period was, like all the others, one of vast extent in point of time. Many changes took place in the earth's surface. The area of the land was increased by the deposit of new strata distinctive of this particular era.

Islands and isolated points of land increased in size and coalesced by the deposit of stratified material. The forest trees still grew, matured and fell, but the Permian rocks locked within their bosoms the great store-houses of coal that had been preserved for the use of man, and has done so much for his comfort and his civilization.

During this long flight of time the law of evolution continued in activity, and a new form of animal life—the **Reptilian**—was slowly emerging. In a subsequent age—the Secondary epoch or Mesozoic age—reptiles made their appearance, but they did not come suddenly upon the scene as complete saurians; they passed through a period of evolution from a preceding lower form—the fishes.

During the Permian period, the mollusks, too, increased in number, variety, size, and complexity of figure. After the first form of mollusk appeared, the little lingula, formed by a mass of cells, absorbing lime from the waters of the sea and elaborating it into a hard external covering or shell, it was easy for this same law to continue in activity and to develop a higher order of activity, a more specialized kind of labor, and so evolve higher and more complex forms of molluscan life. The law of development, once set in motion and stimulated by the higher needs of the animal, and kept in motion by favorable surroundings, went on to the production of extremely intricate shapes among this order of animals.

The curious and beautiful shells of these creatures, with their superb coloring and elaborate designs, are secreted from the soft, perishable bodies and delicate organs that soon disappear. The shell is preserved to us as a permanent record.

The mollusks of the Permian period are less elaborate than those of a later age. In Fig. 32 we see some forms of these mollusks, and by comparison they are found to be on the same plan as the little primary lingula.

In the large shell in the left of the figure *(Monotis Hawni)*, we see an ancient shell that has its prototype in the scallop of our own times, found in abundance along the New York and New England shores. In the pointed shell in the centre of the figure *(Myalina perattenuata)* we also have its prototype in the modern *mussel*, so plentiful in the world, and especially in the western parts of the Straits of Magellan, where I gathered specimens measuring eight inches in length, much larger than any fossils I have ever seen of this period.

There was also a rare and singular mollusk of the

Permian age, the *Productus horridus*. The row of sharp, curved spines on either side of the shell near the hinge are interesting. I have found a similar shell in Panama Bay, and another also near the shores of Guayaquil, having a double row of sharp curved spines. The natives have given them the name of *virgin shells*.

These Permian shells, which are so closely represented by modern forms, are interesting from the fact that they follow through long ages what may be called lines of continuous development—that is, that certain forms of mollusks which at first diverged from the primitive lingula, afterwards set out on a particular line of form, and followed that form closely during great periods of time.

Hence we see the modern clam, scallop, virgin shell, and many others almost identical in outline and figure with those that were developed in the Permian period.

I have in my collection shells of the Tertiary period *(Cardita planicosta)*, which I gathered at Gatun, on the Isthmus of Panama, which are identical in shape to some modern specimens I found in the Gulf of Peñas, on the southern Pacific coast of South America, and some also at the island of Madagascar, in the Indian Ocean.

Both these ancient and modern shells are alike in outline and markings, and except that one is fossil and the other recent, they might be easily mistaken one for the other.

Footprints of a saurian, or some animal closely allied to it, have been discovered near Pottsville, Pa., in our own country. These footprints were made in the soft mud by the animal walking over it, leaving an impression of five fingers in the anterior limb and four in the posterior.

This could easily have been made by a four-limbed lizard of a considerable size, and of a fair degree of development. It is to be regretted that more of these footprints have not been found, or that more of the bones of the animal that made them have not been discovered. But from those footprints we have, the nature and structure of the animal can be studied.

It is probable that these tracks belong to the latter part of the Permian period, for a considerable length of time is required for the evolution of reptilian life from the fishes. It is true that the Carboniferous age was a long one, and there was sufficient time for the development of new forms of life, and while true reptiles did not appear until the succeeding age, it is reasonable to believe that the anatomical and physiological changes they underwent began and continued during this age.

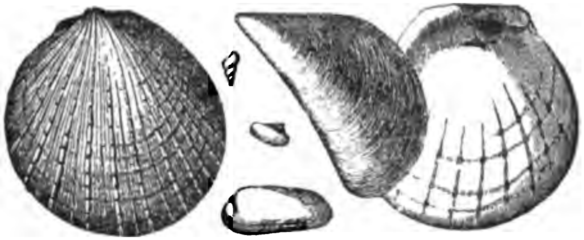


FIG. 32.—MOLLUSKS OF THE PERMIAN PERIOD.

In our museums we see these footprints preserved in stone, and they show that an animal entirely distinct from a fish, and far in advance of him, had made his appearance upon the scene.

Evidently the animal walked on a muddy sea-shore where the waters had left a series of wave-marks, and when we reflect how vast a period of time has elapsed since then, and what great changes have occurred in the earth's surface, the increased area of continents, and the upheaval of great chains of mountains, we are astonished that these footprints and wave-marks have come down to us in so perfect a state of preservation.

Upon examination we see that the fingers have blunt, rounded ends, and that the two outside digits stand a little apart from the rest, a character that belongs more to a fin-ray than to a true digital phalanx. The digital phalanges proper have a more or less free lateral movement, and the power of flexion and extension, and while both the digital phalanx and the fin-ray may stand apart from each other, yet the latter may be readily distinguished from the former. So that while these footprints may have been made by an animal with four or five toes, they belong to a fin-ray and not to a true foot, and hence were of an early form of reptilian life. They evidently belonged to an animal that stood midway, in point of evolution, between a fish and a reptile. In Fig. 33 we see the remains of a skeleton found by Professor Newberry in the coal measures in Ohio.

If we compare this skeleton of a fossil saurian with pterichthys of the Devonian age, we shall see a striking similarity in the external form of the head of the latter with the large bony head of the former. The skeleton shows a development of a scapula, and the anterior limbs have a well-developed humerus, radius, and ulna, as well as the bony fin-rays of an anterior or posterior limb.

The step from pterichthys of the Devonian age to this Permian skeleton of a saurian was not a very long one, nor especially remarkable. We cannot study evolution intelligently by simply looking at the external appearance of animal forms. We must study their *osteology*. The bony skeleton, its varied structure, and its manifold changes, reveal to us the processes that have been going on for ages, whereby one form of animal structure has been changed into a newer one, of a more advanced type, and a more specialized structural development.

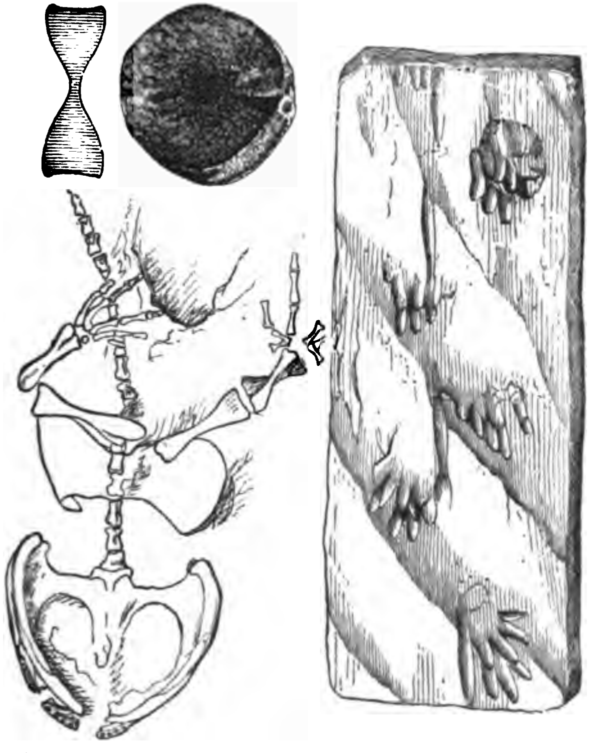


FIG. 33.—SAURIAN SKELETON FOUND IN THE COAL MEASURES OF OHIO.

CHAPTER VI.

THE MESOZOIC AGE:—THE AGE OF REPTILES. THE TRIASSIC PERIOD.

The subdivisions of the Mesozoic age into the Triassic, Jurassic, Cretaceous—Ichthyosaurus—Development of a paddle—Development of a lung—The siredon—The plesiosaurus Development from a shark—The Spinax Blainvillii—True reptiles—Nothosaurus—He is the progenitor of the crocodile and alligator—Mimicry of saurians—Skull of nothosaurus and of crocodile—Labyrinthodon—Development of a leg—First of the pachyderms—Voltzias—Encrinus liliformis—Ceratites nodosus—Development of molluscan shells—The mantlet: its function—Pearl oysters—Nacre—Mussels — Byssus — Univalves — Gasteropods — Limpets — Pearly nautilus—The so-called bird-tracks—Dinosaur.

NEXT in order following the Carboniferous period of the great Paleozoic age is the division of time known as the Mesozoic age.

It was that important epoch in the earth's history when reptilian life became so varied and so abundant.

Geologists have subdivided the Mesozoic age into three lesser epochs, as follows:

The Triassic period.

The Jurassic period.

The Cretaceous period.

It was during these three periods that the great saurians of so many varieties made their appearance upon the earth.

In the preceding chapter we have seen that great trees, destined in a later age to form the coal measures, grew luxuriantly, and formed vast forests of immense extent. The land increased greatly in its area, and extensive, wide-spreading marshes and shallow seas existed over vast areas that are now dry land. Those extensive marshes and adjacent oceans of superficial depth played a very important part in the evolution of saurian life.

The study of the evolution of a reptile from a preceding lower order of animal—a fish—is a subject of the greatest interest. We have already studied minutely the anatomical and physiological changes that led to the development of the fish from his predecessor the sea-worm. We saw that these changes consisted in modifications of the important structure called the cell-membrane. These changes consisted in the folding into plates and ridges of this cell-membrane, and the development from it of certain special organs. Among these organs was the chorda dorsalis, which by segmentation and ossification finally became the vertebral column.

We shall now see that the first great step having once been taken, namely, the formation of the spine or vertebral column, the varied structure of the rest of the great order of the vertebrates follows easily upon the same general plan, by the law of special development for special uses. In the upper part of Fig. 34 we see an animal known as the **Ichthyosaurus**, the fish-lizard. By comparing this animal with the Devonian fish *Cephalaspis*, the differences, which at first appear considerable, diminish greatly upon a closer examination.

In both animals we see a long pointed tail, a continuation of the backbone; we see a series of costal arches or ribs in both; and a large movable head is common to each.

One, cephalaspis, is a fish of the Devonian age; the other, ichthyosaurus, is a fish-lizard of the Triassic or early Mesozoic age; yet they are strikingly alike, the latter being more advanced in special development than the former, but each having many features in point of structure that are common to both. The development of ventral paddles or flippers in the ichthyosaurus is a process of special growth of the external integument, of the same kind that has taken place before in many of the early Devonian fishes, to form the simple fin. Now in the fish-lizard what was formerly the simple fin of the fish has developed into a fin-like paddle, which serves as an organ of propulsion

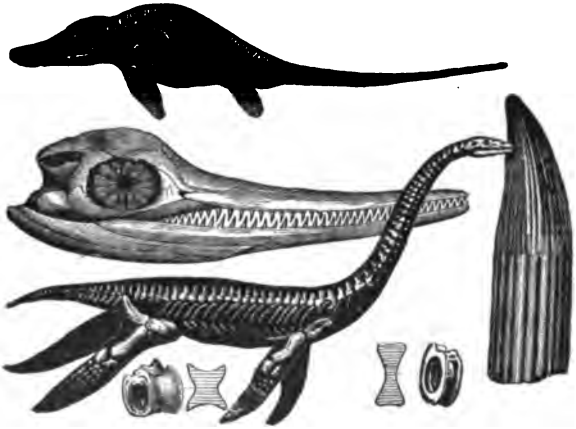


FIG. 34.—ICHTHYOSAURUS AND PLESIOSAURUS.

on the surface of the water. The tail has become partly degenerated or atrophied. As the animal has become fitted to live upon the surface of the water, and can no longer live in its depths, by reason of its being an *air breather*, the tail would degenerate by disuse, and the fins would develop or hypertrophy by use into larger and more completely organized locomotory appendages. Ridges would form in the integument of the fin along the lines of greatest resistance, while at the same time depressions would form along the lines of least resistance. These ridges by long-continued use, by increased nutrition, and by a special kind of activity of their internal structure, and the power to absorb lime and convert it into bone, finally ossified by first forming rays of cartilage, and then depositing lime in this cartilage until it became fully formed bone. In this way, then, by the external development of the integument into ridges, and the internal ossification of these ridges into rays or phalanges of bone, the paddle of the ichthyosaurus was formed.

A factor that aided very largely in determining the development of the bony paddle of this animal was the extensive seas of superficial depth over which it roamed as its favorite habitat in its search for food. As the water near the land where it loved to frequent was too shallow for it to swim beneath the surface, it found its tail of little use, hence it began to degenerate. It was forced to use its fins as swimming organs, and by the law of use an increased development took place externally and internally, until a paddle with an internal bony structure and an external scaly integument was ultimately fully developed.

Besides the development of the bony paddles of the ichthyosaurus, the head of the animal also underwent a series of important changes. The brain increased in size and complexity of function, giving the animal a greater degree of intelligence. The eye developed into a more complex organ, having a circle of facets to the cornea, and each facet capable of transmitting the visual object directly to the retina, thus giving a wide range of vision without moving the head to any extent. The jaws underwent a less change as they were in the fish, elongated by the great development of what in the animal are called the pre-maxillary bones.

These changes in the external configuration of the ichthyosaurus must necessarily have been extremely slow, and were determined by the ever advancing law of evolution towards the elaboration of higher types of animal organisms, by the influence of outward environment, which is very strong indeed, where external conditions determine the development of a new order of locomotory appendages, and the appearance of an entirely new organ, with a function totally dissimilar from any that had thus far appeared—namely, the *lung*.

Hitherto all marine animals performed the office o. the aëration of the blood by means of *Branchiæ* or *gills*, which absorbed oxygen from the water. This function was always performed beneath the surface of the sea.

Now, however, the new organ—the lung—was to take the place of the gills.

In the new animal, the fish-lizard, the old method of purifying the blood by the gills was impossible, because, as it lifted its head above the surface of the superficial seas, the gills could no longer perform this important function, and they gradually shrivelled or atrophied and disappeared.

A new function, that of *respiration* of atmospheric air, now became necessary, and, as a result of that necessity, a new air-breathing apparatus was developed.

The development of the lung in the ichthyosaurus is a process of special growth in the anterior portion of the alimentary canal. This, as we have already seen in the fish, was developed from the internal folds of the cell-membrane.

As the fish-lizard raised its head above the surface of the sea, the gills became of less and less use, until finally atrophy of these organs ensued. At the same time the animal acquired from necessity the power of swallowing atmospheric air, and the œsophagus under this new stimulus soon began to bulge or protrude on either side, and also from its anterior portion. This latter protrusion was the earliest beginning of a *trachea* or *windpipe*. This trachea soon divided into two symmetrical branches which by subsequent elongation and subdivision form the bronchial tubes and their ramifications.

The lateral protuberances of the œsophagus soon coalesced with the ramifications of the bronchial tubes, and in time the lung—an air-breathing organ—was formed, of coarse loose, cellular tissue, capable, however, of purifying the blood by a process of slow and somewhat sluggish respiration of atmospheric air. This slow respiration permitted the animal to remain under water for a considerable length of time, in its pursuits of pleasure or of its prey.

The evolution of the fish-lizard from a fish was a step considerably in advance in the scale of animal life. It was a slow and gradual process, requiring a long time for its accomplishment.

The ichthyosaurus, like its predecessor, the fish, propagated itself by means of eggs. As the young were hatched only the strongest and most vigorous could reach maturity, and these in their turn would transmit to their succeeding progeny the best and highest qualities of their organisms.

In this "survival of the fittest," the young who could resist all their enemies and reach strong adult life would be best able to continue the development of bone, lung, muscle, and nerve tissues.

The formation of a lung in an animal that is at times wholly marine is seen in our own times in the **Siredon,** a species of salamander that is found in our own country, in Mexico, and in Austria. If this animal is kept in water it will develop its gills; if placed on land, these will atrophy, and a lung will form, and the animal will become an air breather. This facility of developing new organs through the power of external influences will help to explain the changes that occurred so long ago in the ichthyosaurus. From the lowly organization of this animal, we must believe that it followed the fishes in the order of evolution, notwithstanding the fact that the footprints of a higher order of animal have been found in the Permian rocks. We cannot believe in the sudden or abrupt appearance of species, or that a higher order was succeeded by a lower one.

Subsequent researches will prove, if it is not proved already, that the ichthyosaurus was next in order of development to the fishes.

A lowly organized air-breathing animal followed one wholly marine in its nature and mode of life.

It is probable from what we know of the form of the ichthyosaurus, and therefore of his habits and modes of life, that he was a lowly organized animal in point of development of his *circulatory apparatus* as well as his lungs.

While we have found no traces of a heart in the fossil remains of the ichthyosaurus, we know that a heart must have existed, and it must have been a true reptilian heart, with an imperfect development, and consequently giving a sluggish circulation to the blood, due to its having *two* auricles and but *one* ventricle. The development of the heart was a special growth of the internal membranous structures, as we have seen in the fishes, forming at first a straight tube, which afterwards dilated at certain points to form the auricles and ventricle. The growth of these two cavities determined the form and size of the heart. The reptiles have a considerable lateral movement of the head, owing to the fact that there is but one occipital condyle connecting it with the atlas, or first cervical vertebra. This gave a considerable mobility to the head.

The ichthyosaurus was a swimming lizard, with bony phalanges concealed in a scaly, thick integument, forming a paddle.

It lived only upon the surface of the water, and while it was able, like all reptiles, to dive and remain for a considerable time beneath the surface, it could not exist long without breathing air.

The true reptiles can move in the water, and also upon the land. In these animals, the limbs have developed beyond the stage of paddles, and were *legs* capable of movement on land, by the process of crawling rather than walking. A true reptile is a step higher in the plane of animal life than the fish-lizard, now under consideration—the ichthyosaurus. While large numbers of fossil bones of this animal have been found in America and Europe, there is reason to believe that it did not flourish greatly, and, in a geological sense, soon became extinct.

The next animal form that demands our attention and study is the **Plesiosaurus.** In the lower part of Fig. 34 we have a view of this singular creature.

Like the ichthyosaurus, the plesiosaurus is a swimming lizard, and therefore not a true reptile. It will be seen by referring to the cut that it has a short pointed tail, its paddles are large and powerful, and its greatly elongated neck rests on a short and fleshy body.

The long slender neck is formed by an unusual development and growth of the anterior dorsal vertebræ.

From the very few fossil specimens that I have been able to study in our own and European museums, I have found that the true cervical vertebræ of this animal have been seven in number. This corresponds to what is true of nearly all the vertebrata—namely, they have only *seven cervical vertebræ.*

Other observers may have seen more complete specimens of the plesiosaurus than I have, but those I have seen warrant my assertion that this animal is no exception to the rule.

The seven cervical vertebræ of the plesiosaurus are somewhat small and flattened antero-posteriorly, which is the opposite to what we find in the giraffe, camel, guanaco, llama, ostrich, and swan of later times. In each of these animals the seven cervical vertebræ are large, elongated, and have a free movement in every direction.

The powerful paddles of the plesiosaurus are developed in the same way as those of the ichthyosaurus, and this is true also of the lungs, heart, and other internal organs. In both animals they were developed alike. As the habits and modes of life of the two animals were identical, and their existence contemporaneous, the principal point of interest is the inquiry as to the origin of the long slender neck of the plesiosaurus. It would seem that among the Selachians of the Devonian age, some of those long, slender-bodied sharks might well be the progenitors of the future plesiosaurus.

Several of those long-bodied predatory Placoids were admirably adapted to undergo the necessary changes, and become in a later age the saurian now under consideration. This is the view I take of it. In the species of Devonian fish known as **Spinax Blainvillii** the dorsal vertebræ are very numerous, and the body is long and slender. There is a small pectoral fin which is almost wholly tegumentary, while the true ventral fins are much larger, and have traces of cartilaginous rays.

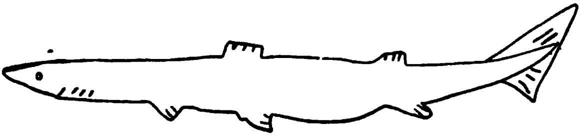


FIG. 35.—SELACHIAN (SHARK) OF THE DEVONIAN AGE—SPINAX BLAINVILLII.

As this animal raised its head above the water in the shallow bays and inlets where it lived, the pectoral fin through disuse would become slowly atrophied and in time disappear. The ventral fins would develop into paddles in the manner already described, and the long anterior portion of the body through successive generations of development, and the survival of the fittest, ultimately become the elongated neck of the plesiosaurus. This view seems at once both scientific and logical, and answers all the requirements.

In Fig. 35 the outline of form of this species of placoid is seen to be such that the special mode of development into a swimming lizard could take place in the course of time, through the force of external influences determining a special development of neck and paddles. The large number of anterior dorsal vertebræ could easily form the long and slender neck of the plesiosaurus.

As it ceased to use its tail as an organ of propulsion in the water, it would follow the simple law of atrophy through disuse, and disappear.

The change of form of a fin to a paddle is an instance of the *adaptiveness of nature* in the development of organs suited to serve a special purpose. Throughout the animal world we see many instances of this, where nature has caused changes to occur to meet the higher needs of the animal. The changes in the special instance of the development of a paddle from a fin consist solely in anatomical growth influenced by external conditions. This growth is an increase in size of internal parts—namely, *the bones*, induced by the efforts of the animal to propel himself on the surface of the sea, where his tail would be of little use to him. The paddles by extraordinary exertion would cause an increased determination of blood to the parts through their appropriate vessels. This would lead to increased nutrition, and consequently to an increase of cell-growth. In the anterior limbs, the humerus, the radius and ulna, and the carpal and phalangeal group of bones; in the posterior limbs, the femur, the tibia and fibula, and the tarsal and phalangeal group of bones, would all undergo an anatomical growth, in strict accordance with the natural laws of growth, and specialized development of parts, and in this way a more complete limb would take the place of one less complete, a more complex limb would follow one less highly organized.

Besides the swimming saurians, of which the huge ichthyosaurus and the plesiosaurus are types, we have ample evidence to show that the *True Reptiles* also appeared in the Triassic period.

There can be no doubt that the reptiles proper followed in order of evolution the great swimming saurians, for the reason that they belong to a more advanced anatomical organization. The ichthyosaurus and the plesiosaurus were swimming saurians only, and were confined wholly to the sea, and had no power of crawling upon the land, while the true reptiles were able to crawl upon the land, as well as to swim in the sea, in consequence of a more completely developed leg and foot, adapted to both an aquatic and terrestrial mode of life.

In Fig. 36 we see a true reptile in the act of crawling over the rocks as he emerges from the sea.

The formidable array of dorsal crests and spiny protuberances are merely an increased growth of external scaly integument, and do not affect its true anatomical organization and internal structure.

Adopting the same mode of reasoning, it is extremely probable that this saurian is an evolution from one of the earlier Devonian placoids, perhaps from the Spinax Blainvillii. The change from a shark with gills to a lizard with lungs is one that could easily take place in the manner already described above. It is a true physiological transmutation of function.

In this reptile the most important advance in structure is the development of the bones of the anterior and posterior limbs, enabling the creature to crawl upon the land. The tail has undergone no atrophy, it is still an organ of aquatic propulsion, and is large and powerful. The scales of the fish, under the influence of the air, have been replaced by a thick pachydermatous skin, capable of a double or amphibious mode of life.

The head, jaws, and teeth have undergone a considerably advanced development. In the configuration of the jaws, in the formidable dentition, and the powerful tail, we can see that the animal has developed a ferocious nature and predatory habits.

What induced the development of legs from the fins of a fish? Undoubtedly the continuous efforts of the animal to move itself over shallow sea beds, and soft, low marches which stretched away over such vast areas. The law of use, or long-continued effort, by causing a greater degree of nutrition of the parts, brought about the simple anatomical changes which led to ultimate greater complexity of structure. It was a special growth of special organs. Thus changes in the surface of the land induced changes in the anatomy of animals.

These two important changes progressed simultaneously—a continuous upward movement in geological formations, an accompanying upward movement in plant and animal life,—and these induced an increased anatomical development. This reptile—a true saurian—has been called the **Nothosaurus.**

He stands at the head of his class of that period, and his characteristics have come down to us and are seen to-day in the **Crocodiles** of the Nile and the Ganges of Africa and Asia, and the **Alligators** of the Mississippi of our own country.

In Fig. 37 we see in this reptile, which is a true modern crocodile, a striking similarity in form to the

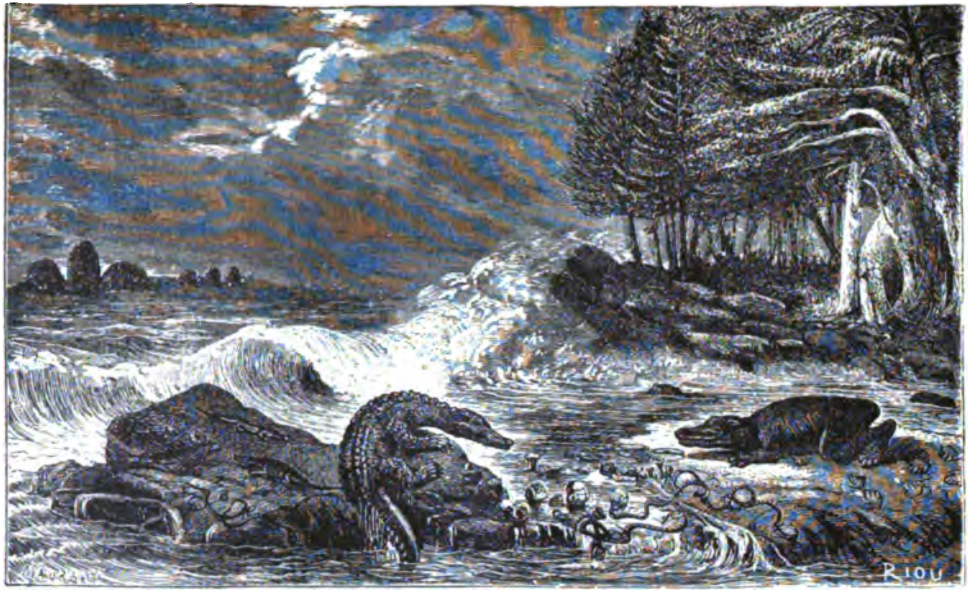


FIG. 36.—NOTHOSAURUS OF THE DEVONIAN AGE.

nothosaurus of the Triassic age. The ancient saurian has transmitted, through a time that may be counted by millions of years, his anatomical characteristics in an almost unbroken line. This is another example of what I have called continuous development, where the same animal forms have followed the same lines of external anatomical configuration throughout long geological ages.

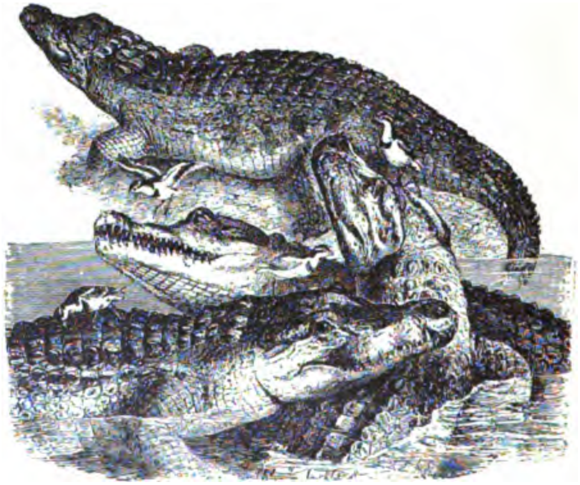


FIG. 37.—MODERN CROCODILE.

The type of reptilian life known as the **Gavial** of the Ganges River in India differs slightly in form from the African species of Nile River crocodile. Here again we see the transmission of an ancient form in the long pointed jaws—pre-maxillary bones—and sharp teeth, which so closely resemble those of the ichthyosaurus.

In Fig. 38 we have the alligator, a true saurian, now found in the Mississippi River in its southern part. I have seen these creatures in great numbers along the marshy shores of this river.

While in Brazil I saw this same species of alligator on the Amazon River for a distance of more than two hundred miles above the city of Pará, and while I did not have the opportunity to hunt them in boats as I did on the Mississippi, and so observe them as closely, I could see no essential differences as to their external anatomy between them.

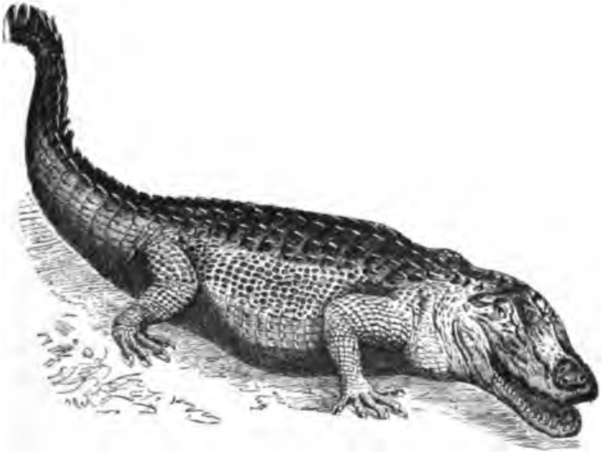


FIG. 38.—MODERN ALLIGATOR.

Both species are alike in their habits and modes of life, both are ferocious and predatory, and both have the same habit of lying perfectly still close to the water's edge until their prey comes within reach, when, with a sudden stroke of their powerful tails, they knock it into the stream and eat it leisurely after drowning it by dragging it under the water.

The *mimicry* of these creatures makes them easily mistaken for logs.

On the Amazon I saw one of them lying near the water. A small troop of monkeys came down to the river to drink. One of them bolder, or perhaps more innocent than the rest, jumped on the alligator's back, and for a full minute sat there undisturbed. I thought a friendship existed between them, when a sudden blow from the reptile's tail threw the monkey screaming into the water. A quick plunge, and both disappeared from sight.

The same thing occurred in Louisiana. I was deer hunting one day with a valuable bloodhound, when the dog went to the edge of the Red River to drink. I followed close behind him on horseback. He sprang on what seemed a cotton-wood log and began to lap the water. Before I could realize what happened, I saw the dog flying through the air, and the seeming "log" dart quickly into the water. As the hound fell into the river the open jaws of the alligator were ready to receive him, and both disappeared with a gurgle from my view.

There is abundant evidence to show that the nothosaurus of the Triassic period was the progenitor of the modern crocodile of the Nile, the gavial of the Ganges, and the alligator of the Amazon and the Mississippi.

The nothosaurus varied in length from three to thirty feet. Fossil bones have been found showing it had attained this latter measurement.

The modern saurians seldom exceed twenty feet, the average being not far from ten feet.

A comparison of the skulls of the ancient nothosaurus with those of the modern crocodile will show some points of difference and some of striking similarity.

The main differences are those of higher development in the modern saurian, especially in the dentition of the two animals. The teeth of the nothosaurus are less highly developed, being set somewhat loosely in the alveolar process of the jaw. All teeth belong to the tegumentary system, and are developed from it. Those of the nothosaurus are sharp and pointed, and are inserted in the jaw in a continuous row.

In studying the bony anatomy of these saurians, we see the early and low order of development of the skull of the nothosaurus. The pre-maxillary bones are long, smooth, and straight, and the lower jaw is loosely articulated to the upper entirely by ligaments. There is no condyle of the lower maxillary bone, and no fossæ or spinous processes, thus showing that the muscles were very slightly developed.

If we examine a skull of the modern crocodile, we see a well-marked condyle of the lower maxilla, and fossæ and spinous processes for the insertion of muscles. There is also an inferior dental foramen for the transmission of the dental nerve, and the bony orbits are permanent. The teeth are set firmly into the jaw-bone, the alveolar processes being quite solid. The teeth are isolated, sharp, and pointed, and are covered with a layer of hard enamel.

These differences serve to show that the modern saurian, the crocodile, and the gavial are more highly developed in the structure of the teeth and the bones of the head than the ancient nothosaurus, the general form and outline in both remaining nearly the same.

A new and strange animal that appeared in the Triassic period—the **Labyrinthodon**—will next demand our special study and attention. The fossil remains of this singular creature have been found in several localities in our own country and in Europe. It seems to have been the first of wholly terrestrial animals that appeared upon the earth. It possesses qualities that are both reptilian and mammal. It was regarded as a huge batrachian by many geologists, and it had some points characteristic of that order of animals. There is little doubt now, however, that it was a terrestrial, air-breathing reptile, living wholly upon the low marshy land, and having no affinity for the sea. A glance at Fig. 39 will show us how this remarkable animal looked when alive.

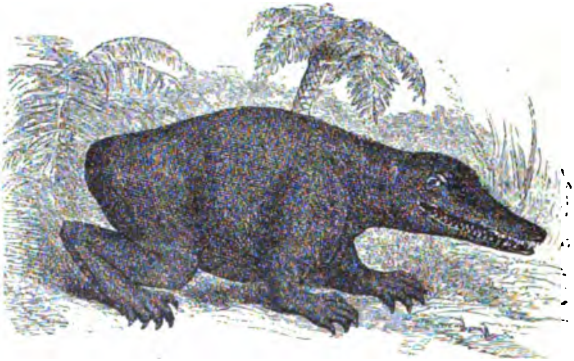


FIG. 39.—LABYRINTHODON.

Its head closely resembles that of the ichthyosaurus and the nothosaurus. It has no tail, the body is short and stout, and the legs are large, and are more like those of a batrachian than a mammal. Still even now we can see in this animal the true leg of the mammal foreshadowed. Its movements must have been sluggish, but its habits predatory, to enable it to subsist on other animals. Its dentition is peculiar, and in advance of the true saurians, for each tooth has a highly complicated structure, owing to a folding of the pulp while in an early stage of growth. This arrangement of the tooth pulp into corrugated layers, set longitudinally in the tooth, has given the animal his distinctive name.

The labyrinthodon was a transition from a swimming reptile to a true mammal. It was cold-blooded, and reproduced its young from eggs.

We must believe that it was evolved from the ichthyosaurus, and that the anatomical changes that were necessary for the production of such an animal form were quite simple, and in entire harmony with the laws that govern such changes. The ichthyosaurus was, as we have seen, an air-breathing animal that lived upon the surface of the waters forming the shallow bays near the land. The younger ichthyosauri, in their sea and marsh mode of life, necessarily soon acquired the habit of crawling on the low swampy shores of the sea, partly from a desire to do so, and partly in search of food. In doing this they would be compelled to use their paddles as locomotory organs. An increased nutrition of the parts would soon follow, resulting in an increased growth of the bones. The more vigorous of these saurians preferably lived more and more upon the marshes, until they found them a permanently congenial habitat. In this new existence the tail would be of no use, and it would atrophy and finally disappear. The limbs, which, as I have said, were not true legs, but a thick, heavy locomotory appendage, developed in a manner that was quite simple. All the bones increased in size, as a result of an increased flow of blood to the parts, or increased nutrition. Bones grow by the absorption of nutrient materials from the blood, and the bones of the labyrinthodon grew in the same way. As the body of this animal was heavy, he needed a heavy limb to support his weight. He required an uninterrupted and liberal supply of food, and this formed a large quantity of blood from which the bone material was elaborated. The lowly developed bone of the ichthyosaurus became the more highly developed bone of the labyrinthodon, through the law of use and greater nutrition.

The changes that took place were an increased growth of the femur, and of the tibia and fibula. The femur was almost wholly concealed in the flank, the knee-joint lying close against the flank.

The metatarsal bones were very long, and gave a doubled shape to the limb.

In the ichthyosaurus the phalangeal bones of the paddle were concealed in a thick tegumentary web, admirably adapted for swimming in shallow seas. In the labyrinthodon the long-continued efforts of crawling on marshy ground would lead to a greater development of these bones, until ultimately they would be slightly separated from each other, and become rounded on the distal extremity. This would cause the foot to leave an impression of its five toes in the soft mud over which it passed.

The formation of a pelvis, at first very simple, would follow as the animal grew heavier, and the head of the femur needed some point of support. The posterior lumbar vertebræ would throw out lateral processes which would finally develop into true pelvic bones.

The bones of the fore-leg would develop in precisely the same way, but in addition to an increased growth of the humerus, the radius and ulna, and the separate development of the toes, a scapula or shoulder-blade would be formed to receive the upward thrust of the humerus, and to raise the anterior part of the body from the ground.

The development of the scapula would result from the gradual ossification of the cartilaginous end of the humerus, and its extension upwards from increased growth into a broad and flattened bone.

The head of the labyrinthodon underwent but little change. It largely retained the characters of the ichthyosaurus.

The external integument could not have been scaly, as the animal lived wholly upon low marshy ground. It was a *terrestrial* animal, and while it could no doubt swim if thrown into the water, it was not aquatic in its habits. Its skin must have been thick and dry, owing to the influences of air and light upon it. The labyrinthodon was the first of the true *pachyderms*.

In this way, then, the anatomical structure and configuration of the ichthyosaurus became changed, and a new animal, the labyrinthodon, appeared. As the ages passed, he in his turn was destined to undergo a change, and finally to pass away and give place to still newer and higher animal forms.

New modes and habits of life and a change of external environment are powerful factors in causing changes to occur in the forms of animal life. The survival of those best fitted to transmit the new qualities to their successors would continue these changes indefinitely. The weaker would succumb and disappear. Thus far, climates had no effect in producing such changes, for up to this point of geological time no climate existed. A uniformly warm temperature extended all over the earth. The seas were still warm and fresh. The low Laurentian Hills remained fixed in their primitive repose, and great marshes stretched away everywhere. The Carboniferous forests were still luxuriant and covered immense areas with rich and graceful verdure. A new species of tree made its appearance in this period, namely, the Voltzias. In Fig. 40 we have a restoration of the branches and needles and the cones of this beautiful tree.

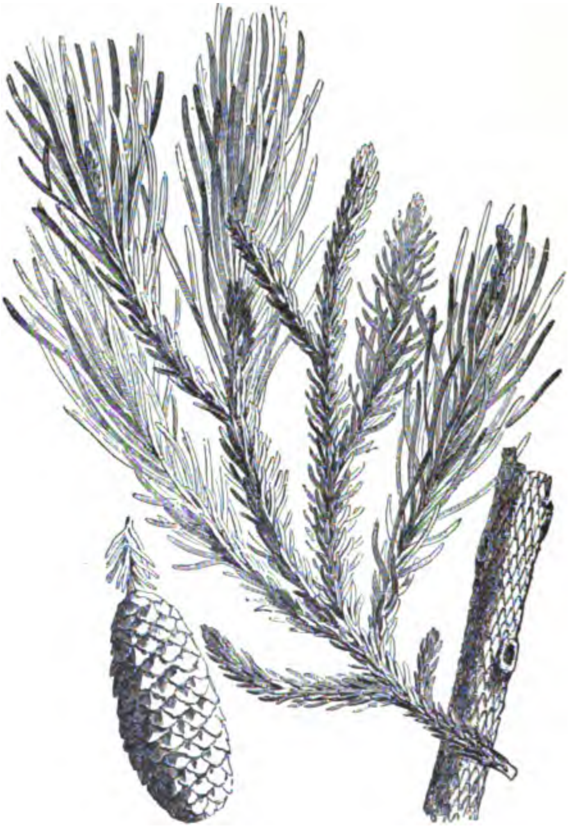


FIG. 40.—VOLTZIA OF THE CARBONIFEROUS AGE.

We see here a foreshadowing of the modern pine *(Pinus strobus)*, the hemlock *(Abies)*, and the cedar *(Cedrus)*. The voltzia has transmitted some of its characteristics to our own times. The variations in the external appearances of plants are due to varying conditions of soil, light, moisture, and freedom from repressing influences. Plants follow an upward tendency of development as well as animals. They grow by an increase of cells or cell-tissue, and this increase of cell-tissue is determined by the power of the plant to absorb nutrient materials from the soil in which it is rooted. A rich and generous soil, with a favorable supply of heat and moisture, immunity from destructive enemies, and ample space to grow, determine very largely the character and form as well as the habits of the plant.

The heat and moisture and the marshy ground of the triassic period were quite as favorable to forest growth as were the same conditions in the Carboniferous age. All plant life of the earth up to the Trias was of a comparatively simple kind. No fruits, nor fragrant, brightly colored flowers existed. The forest trees were of a light cellular texture that grew rapidly in the warm air, abundant rains, and swampy ground of that age. They were all flowerless plants, and quite simple in their botanical construction. No new species of radiates or mollusks appeared in the Triassic period. The crinoids or sea-lilies of the Devonian age were continued into the Trias, and one species, the *Encrinus liliformis*, or lily-crinoid, was especially abundant and beautiful. This species of radiate grew in such profusion in the clear seas of the Triassic period that its stony remains form extensive beds of limestone. A view of this pretty cephalopod, or stone-animal, is shown in Fig. 41, and we see very plainly the cellular character of its parts before it turned to stone by the absorption of lime from the water in which it lived.

There were few mollusks also of this period. A form called *Ceratites nodosus* was found in great numbers but over restricted areas in our own country and Europe. In this mollusk we see the forerunner of the famous ammonite which appeared at a later age. The evolution of the mollusks into their numerous and complicated forms is a subject of great interest. The primitive lingula of the Upper Silurian age is the parent from which has sprung the immense array of shell formations, an enumeration of which would fill a volume.

We have already studied the process of the formation of the shells of the lingula. We have seen that the soft body of the little animal absorbed lime from the sea, and elaborated a thin external covering or shell for its protection. Two shells were formed from the cell-membrane. This cell-membrane very early developed into a fold or *mantle.* This mantle became a constant and important structure throughout nearly the whole order of the mollusca. From the mantle the various and complicated forms of shells are elaborated.

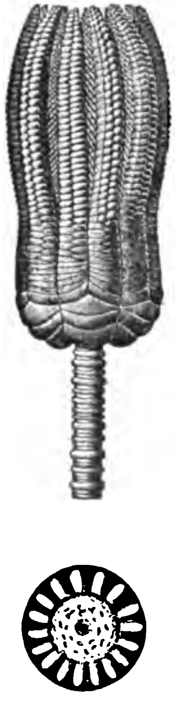


FIG. 41.
LILY-CRINOID

The mantle itself was formed in the first instance by the folding of the cell-membrane into two parts or sides, forming two lateral folds which came in contact along one of its edges. On the free edges of the mantle there were formed a row of *follicles*, which have a gland-like function. The follicles, which are small rounded bodies, are composed of extremely small cells, arranged in such a way as to give a central cavity and numerous openings into it. The follicles have the power to secrete a sort of fibrous animal matter, and to mix with it lime which they absorb from the water. When the proportion of lime is large the shell is hard, brittle, and stony, when it is small the shell is more fibrous and less brittle in texture.

This material, composed of animal matter and lime, is deposited in successive layers around the soft body of the animal. The layers overlap and partly coalesce, and in time a complete shell is formed—one on each side. Each side of the mantle secretes its own shell, and in this way the two shells are formed. We then have a **Bivalve Mollusk.**

All the ancient bivalves, down to the modern scallop, mussel, oyster, and clam, were formed in this way. The inequalities on the external surface of some shells, the rows of flutings, ridges, and spines, are formed by the varying activities of the mantle-follicles, secreting at one time an excess of lime, at another of animal matter, and at another an excess of both.

The interior surface of shells is generally smooth, white, and nacrous, and in some is brightly or iridescently colored.

The pearl-oyster catchers of Panama Bay have told me that if the pearl-oyster was planted in quiet waters, where it could remain for a time free from disturbance, it would develop the pearly-white *nacre* rapidly. This nacre is sometimes so pure and lustrous that it is cut and polished in rounded masses, called oriental pearls, to imitate the true pearl that the oyster secretes in the folds of its mantle. These shells are largely used to make the so-called pearl buttons. The true pearl, which is prized so highly as an ornament, is formed in the mantle itself. The follicles secrete the nacre in small masses which are found when the oyster is opened. If a grain of sand or other foreign body be purposely introduced into the folds of the mantle it will be at once coated with a layer of nacre to render it less irritating to the oyster.

The modern sea-mussel (*Mytilus edulis*), so common throughout the world, is doubtless a descendant of the lingula of the Upper Silurian age. In this mollusk the shells are largely composed of animal matter and are nearly black in color. The interior of the shell is very dark also, and the body of the animal of a pale yellow. It attaches itself to the rocks by means of fibrous threads which are secreted also by the mantle. This is the *byssus*.

The mussel is esteemed as food, and grows abundantly and sometimes of great size. In the Straits of Magellan I found them growing by millions on the rocks near the Pacific entrance and along up Smyth Channel, where the fall of the tide does not uncover more than two feet of the rock. Here they grow from six to nine inches in length, and are devoured greedily by the Terra del Fuegan savages. I saw in several places on the shore large mounds of mussel shells, and near by charred embers where the savages had roasted them for food.

This, then, is the process by which the two shells of all bivalve mollusks are formed. While this order of animals is large, it is small in comparison with the

Univalves, or those mollusks having a single shell. The univalves are generally unfit for food. They are almost countless in variety of form and size, of outline and color. They are gasteropods, or animals that creep or glide by the successive expansion and contraction of the under side of the body, which forms a broad muscular foot. However numerous their varieties, or how different their shape, they all come under the order of *snails*

The shell of the univalves is secreted in precisely the same way as the bivalves—by the follicles of the mantle. In the univalves the two halves or sides of the mantle become joined at the extremities so as to form a circular mantle. This circular mantle secretes at first a single point of calcareous matter, which increases in size by the addition of successive layers until a single shell is formed sufficient to cover and protect the body of the animal.

In univalve shells that have cones, complicated ridges, spines, and fluted or serrated edges the process of formation is essentially the same. They are all formed by the follicles of the mantle secreting an excess of animal matter to form projections at certain points—or spines—and ridges or flutes at other points by an excess of lime. The variegated and beautiful colors possessed by many shells are formed under the influence of the sunlight acting chemically upon the mineral and animal constituents of the shell when they are first secreted by the mantle-follicles.

We have, then, two principal orders of mollusks—bivalves, or animals with two shells joined by a hinge, and univalves, or animals with a single shell. In both, the shell was formed to protect the soft body of the animal, and in both, the shell, however elaborate or complicated in structure, was secreted by the animal itself from a row of gland-like follicles situated usually in the free border of the mantle. These follicles possessed the function of absorbing lime from the water and elaborating it, by successive layers, into a hard, durable shell, more or less intricate in structure and design, and ornamented by brightly colored hues.

The geographical distribution of ancient univalves and bivalves, as well as modern, is very extensive. I found fossil limpets *(Patella vulgata)* . at Gatun, Isthmus of Panama, of the Tertiary period.

They, with several forms of Gasteropods, notably *Vivipara retusa*, were exceedingly abundant, and formed hillocks of considerable extent. Some of them were so well preserved that I at first thought they must be recent. I found a similar species, probably of the Carboniferous period, on the coast of Chili, about twenty-five miles south of Lota, imbedded with fossil tree-trunks in sandstone, which was being slowly worn away by the action of the sea beating against it. I also found shells of a like species on the east coast of Africa, near Mozambique, where they formed foot-hills of considerable size. They were also of the Tertiary period, and were imbedded in a fine gray sandstone.

They are identical in structure and appearance to recent shells I have gathered in Terra del Fuego and on the east coast of Patagonia, also on the island of San Domingo, and in several localities in our own country.

Great numbers of fossils have been found of the *Ceratites nodosus*, a cephalopod, which was abundant in the Triassic period, and which subsequently became extinct.

This animal was followed by the ammonites, and in the Tertiary period and down to our own times is represented by the beautiful pearly nautilus (*Nautilus pompilius*).

In all these complicated species of univalves the same great law of evolution underlies each in its elaborate development.

The different chambers or septa in the convoluted shell of the animal were secreted successively by the mantle-follicles. They assumed the coiled or convoluted shape by the secretion of calcareous matter more abundantly upon the periphery than upon the inner curve of the shell. The primary convolutions were formed, doubtless, by the habit of the animal while in an unprotected state of coiling himself up partly to escape danger and partly to float more easily upon the surface of the water when necessary, although it lives generally at the bottom of the sea, and not usually on the surface.

At the close of the Triassic period the aspect of the land had undergone many changes. Dry and more elevated areas of the earth's surface became more extensive as it was slowly uplifted above the sea. The marshes were slowly filled up by materials washed down from higher levels. The forests were still widespreading, and grew luxuriantly in the heat and moisture.

Reptilian life found congenial conditions for its enormous development. Some new and strange forms appeared, and the seas swarmed with those uncouth monsters now so completely unknown except from their fossil remains. Rapacious fishes abounded in vast numbers. Molluscan life developed a great number of new and intricate forms.

The more extended areas of high and dry land, and the consequent change of the character of the flora, and a clearer and dryer atmosphere, through which the sun's rays could reach the earth unimpeded, exerted a vast influence in the evolution of more advanced and more specialized types of animal life.

Up to this period the highest order of animal possessed characters which were decidedly saurian. No true mammals existed, no birds, and but few insects. Crustaceans advanced slowly, but the general tendency was always upward to a higher and more complete anatomical development in the great order of the animal kingdom.

In the later Triassic rocks geologists have found in several localities in our own country footprints which were long thought to have been made by birds. These so-called bird-tracks are now known to be the tracks of a reptile—the **Dinosaur.** This animal walked on his posterior limbs, which were large and capable of supporting his body, and rarely brought his anterior limbs to the ground for the purpose of locomotion. He was, in fact, a reptile which raised his body from the ground and walked in a more or less upright position.

Here we see a foreshadowing of two animal forms that were yet to appear—namely, **marsupials** and **birds.** As the dinosaur appeared in the later ages of the Triassic period, and reached his greatest development in the Cretaceous period, we naturally inquire from what preceding animal was he descended. It is very probable that the nothosaurus was his progenitor. We have seen that the nothosaurus was a true reptile, with such a development of leg as to enable him to crawl upon the rocks near the sea, and also upon the land. In the course of time this animal, in his pursuit of prey, gradually acquired the habit of raising himself upon his posterior limbs. This habit was transmitted to succeeding individuals until it became the favorite and permanent position of the animal, and this divergence of development from the nothosaurus finally led to the formation of a new animal, the dinosaur.

CHAPTER VII.

THE MESOZOIC AGE:—THE AGE OF REPTILES. THE JURASSIC PERIOD.

The Black Hills, Dakota: their formation—Ammonites—Belemnites—Common squid—Cuttle-fish—Octopus—Pterodactyl—He is the progenitor of the modern bat—Powers of flight of the albatross—Ramphorynchus—Teleosaurus—The great Jurassic marshes—Viviparous propagation—The change from a saurian to a marsupial.

THE name *Jurassic*, as applied to this second subdivision of the Mesozoic period, is derived from the fact that the range of Jura Mountains on the western border of Switzerland were uplifted above the sea at this time. The upheavals of land that occurred elsewhere during the same age have been called Jurassic rocks, or formations.

Geologists in Europe have divided the Jurassic period into three lesser subdivisions—namely, the Lias, Oölite, Wealden.

The plan and scope of our work, however, does not require a special study of either, except to show that some particular type of animal life made its appearance in one of these lesser subdivisions of geological history.

This second division of the Mesozoic age—the Jurassic—while it followed in orderly succession the Triassic, showed some great steps in advance, both in the character and topography of the land, and in the evolution of new forms of life.

A phenomenon of great geological interest was the upheaval of what are now known as the Black Hills, in Dakota, in our own country. These hills are of considerable extent and importance. They are composed of three kinds of rock—namely, primitive Archean rock, Potsdam sandstone, Carboniferous limestone. The base of Archean rock formed a part of the primitive solid crust of the earth. The Potsdam sandstone was formed next above it by the washing down of eroded materials from the adjacent Laurentian Hills, and the limestone was formed under the sea in a superimposed layer during the Carboniferous age. An internal upheaving force raised these several strata above the sea-level, and what are now a cluster of large and important hills, standing isolated in the midst of a wide and level plain, were in the Jurassic period an island of considerable extent, surrounded by a shallow ocean; on the north were the contiguous Laurentian Hills, as they bent away towards the Arctic Ocean; on the west, south, and east was a superficial sea, with scattered numerous islands, and still farther to the southeast were extensive marshes and dry land. The highest point in these hills at present is about 7,400 feet above sea-level. But when they were first uplifted they must have greatly exceeded this height, as they show marks of extensive erosion and wear. The Black Hills have a geological interest as being the only upheaval of any consequence that occurred in our own country in the Jurassic period. The local interest attaching to these hills is their famous history as the resort of gold-miners within a few years past, and the sanguinary strifes of these miners with tribes of hostile, copper-hued Indians, a remnant of the aboriginal races that were found on the discovery of America. These Indians resented the advances of civilization made by the white man, and waged a savage warfare upon him, until conquered by a superior intelligence.

Among the mollusks of the Jurassic age were the **Ammonites**, a complicated shell with an intricate and convoluted form. They were very abundant, and attained a very considerable size.

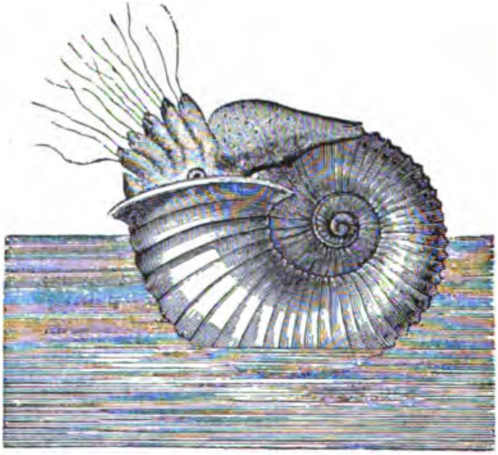


FIG. 42.—AMMONITE OF THE JURASSIC AGE.

The ammonites were a continuation of development, doubtless, of the preceding order, *Ceratites nodosus*. They were a chambered animal, a cephalopod, and lived usually at the bottom of the sea.

In Fig. 42 we have a restored view of one of these animals floating gracefully upon the surface of the sea. It is rather fanciful, however, for the ammonites could not live on the surface of the water. They dwelt on the bottom.

It has been supposed that the posterior chambers, which are empty, and which are connected by means of a tube or siphuncle, could be filled with water by the animal at will, and allow him to sink, or he could empty them, and so rise and float on the surface. As the animal secretes the chamber-shell successively from the small to the greater end, and as he only occupies the greater or anterior chamber, this view seems untenable. His structure and mode of life would lead him to fix his habitat on the sea floor, where his food was always found. The siphuncle has no apparatus, as far as we can discover, whereby it could fill or empty the posterior chambers. The fossil specimens I have examined in the museums of Europe and our own country would lead me to believe that the animal lived from necessity at the bottom of the sea. The empty chambers served no purpose whatever. The tentacles surrounding the mouth of the ammonites show the predatory habits of the creature, and foreshadow the cuttle-fish and the octopus of a later age.

The method of development of the complicated structure of the ammonite shell follows the same law as that of ceratites nodosus. The animal possessed a circular mantle, and from this the chambers were in turn secreted, in successive and concentric layers, the lime entering into their composition being absorbed from the sea water by the mantle.

Another singular mollusk of the Jurassic age was the **Belemnite,** a rapacious cephalopod, which also lived at the bottom of the sea.

A reference to Fig. 43 shows us that this animal lived in a simply formed, straight shell, pointed at the posterior extremity, and open at the anterior, to accommodate the mantle, head, and long tentacles of this interesting creature.

The tentacles were highly developed. They were powerful, long, and flexible, and served as prehensile organs.

Their development was due to an increased cell growth in the muscular tissues of the tentacle, owing to *use*, which stimulated the nutritive processes of the part.

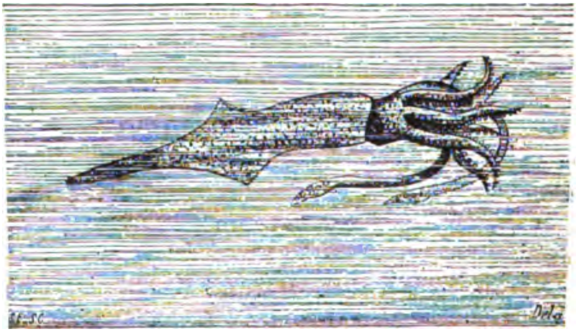


FIG. 43.—BELEMNITE OF THE JURASSIC AGE.

The belemnites possessed a curiously formed sac with an external orifice, which was filled with a black liquid. The contractile muscular apparatus of this sac was under the nervous control of the animal's will, and by a slight compression of the sac he could eject a quantity of this inky fluid into the water. This served to conceal him from his enemies and allow his escape. See Fig. 44.

This device of a sac of colored fluid as a means of defence has been preserved to our own times, and is seen in the sepia and octopus very markedly. The same device is also seen in some terrestrial animals, notably the skunk *(Mephitica mephiticus)*, but in this animal, the fluid being thrown into the air, is not dark-colored, but is of a foul odor. It is a means of defence in both cases.

The evolution of the univalve mollusks shows a striking progress from the early lower forms to the ceratites, the ammonites, and the belemnites.

In ceratites we have one of the earliest forms of development of the tentacle, an elongated, muscular, prehensile organ or arm, formed by increased cell-growth, due to a greater flow of blood to the parts, and causing a greater degree of nutrition and special development of an organ to meet a higher need of the animal.

In the ammonites we have the tentacles still more highly developed. The mantle is more perfect in its functions, and hence it secretes a more perfect and more complicated shell. The extreme activity of the secreting powers of the mantle leads to a great increase in the size of the ammonite's shell.

In the belemnites the shell retrogrades and becomes more simple in construction. The animal, obedient to his rapacious nature, pursues his prey with greater fury, and this increased activity leads to an increased growth of the tentacles and a greater complexity in their muscular structure, as well as a more highly developed function.

The development of a muscular tentacle as a prehensile organ exceeded in the belemnite those of all other ancient univalve animals.

In modern times we have several forms of cephalopods the tentacles of which have been transmitted from the ancient types. In the common squid *(Loligo vulgaris)*, which is found plentifully in our country and Europe, the tentacles are strongly developed. A striking example of this is seen in a specimen in the Yale Museum at New Haven. This is also true of the Cuttlefish *(Sepia elegans)*. Both these animals are univalves, and bear a strong general resemblance to the ancient belemnites. They also have an ink sac, which is used to discolor the water and facilitate their escape when pursued by destructive enemies. The ink is secreted by the lining cell-membrane of the sac, which has the power to absorb water and deposit in it a large number of minute pigment cells, which give it its intensely black color.

A species of cuttle-fish of gigantic size is occasionally found on the coast of Newfoundland. Such an animal is shown in Fig. 44.

An animal of such monstrous size is an extraordinary development, under peculiarly favoring circumstances, of the common cuttle-fish.

While cruising in the U. S. Ship *Ino*, near the Cape de Verde Islands, I saw one of these animals, of immense size. It appeared close to the ship's side as we were sailing slowly along, and while I had a perfect view of it, I could only approximately estimate its size. I should say that its body was at least ten feet in length, while its tentacles, which it moved freely about, seemed to be six or eight feet in length. While we were preparing to throw an "*iron*" into it, with a view to its capture, it sank below reach, much to our regret. It moved in the water with but slight effort, and stared at us with its wide-open and unpleasant eyes. He did not discolor the water with his ink as he disappeared, because he was not alarmed or excited.

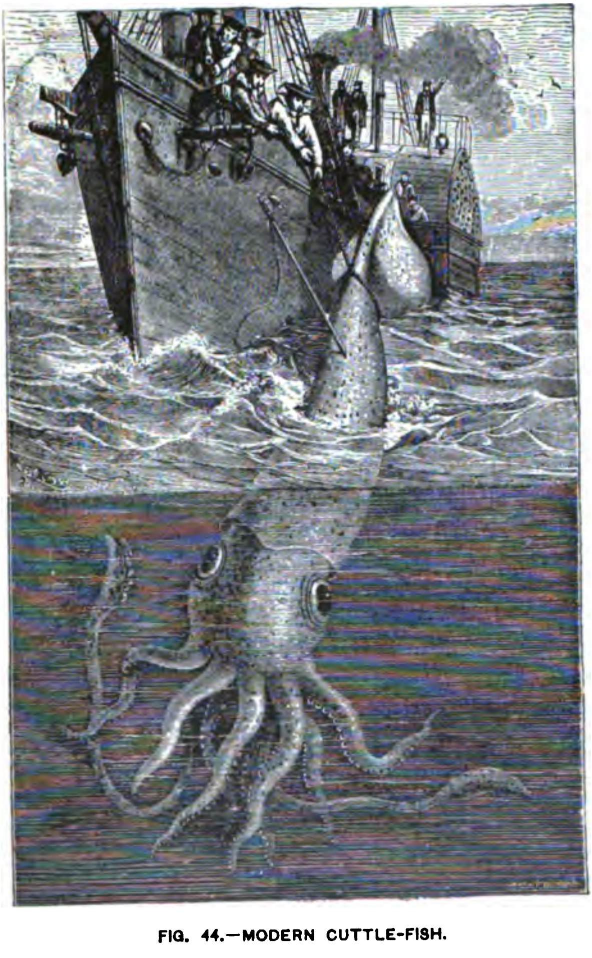


FIG. 44.—MODERN CUTTLE-FISH.

The modern octopus is another univalve cephalopod of great size and enormously developed tentacles. The shell is small and rudimentary, but it is, nevertheless, a true univalve.

Size is only relative, and if we compare this animal with his modern and his ancient prototypes we shall see the same plan of construction, the same habits and modes of life, the differences being in the varying complexity of the shell, and of the development of the tentacles surrounding the animal's head and mouth. The enormous tentacles of the octopus are a continuation of development of the tentacles of the Jurassic ceratites.

In Fig. 45 we have a view of the modern octopus.

An enormous specimen of the octopus is seen in the Yale Museum at New Haven.

The appearance of the **Pterodactyl** in the Jurassic period marked a new step in advance in the evolution of animal life. This half-animal and half-bat was a saurian, and was evolved from a former type of saurian.

By a reference to Fig. 46, we see a sketch of this creature, so unlike any of his contemporaries.

It becomes an interesting inquiry how such an animal, so unique and perhaps uncouth in appearance and outward form, could be evolved from any preceding form. Such an inquiry becomes greatly simplified upon examining its osteology. Upon a close study of the fossil bones of this animal which have been preserved in our museums, we see that the saurian characters of the skull, the cervical and dorsal vertebræ, the ribs, and a part of the bones of the legs, have been preserved.

It was a half-flying saurian, with an enormous development of external integument.

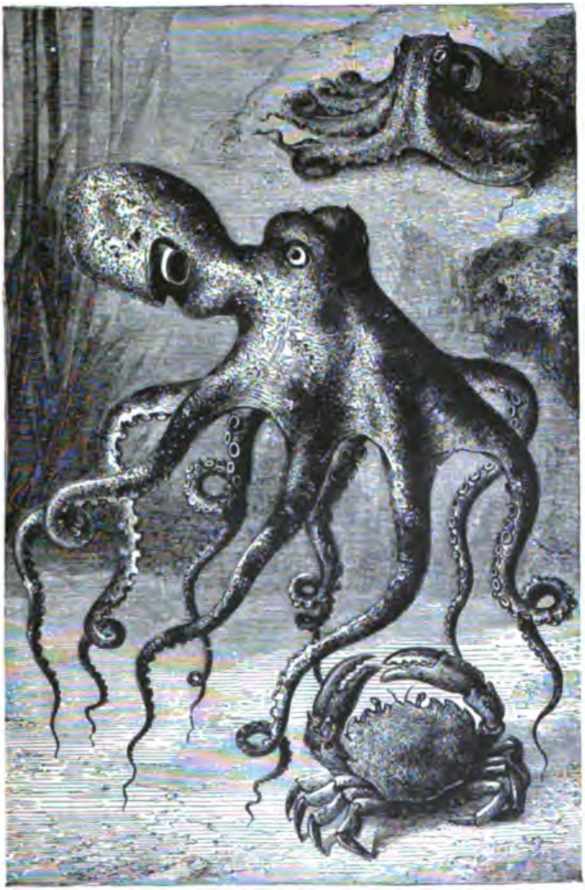


FIG. 45.—MODERN OCTOPUS.

We are forced to believe that the pterodactyl was evolved from some preceding saurian form, and it is very probable that such a saurian form was the plesiosaurus. The anatomical changes necessary to transmute a swimming saurian to a half-flying terrestrial saurian could easily take place in the lapse of time. The plesiosaurus gradually found himself in more and more shallow water and on extensive marshes. In order to obtain sufficient and congenial food, he must seek it amid new and changed aquatic and terrestrial conditions, and to capture it he must throw himself upon it, as he can no longer swim with his former facility. This *forced* act of throwing himself gradually developed his posterior paddles into a more *leg-like* limb, and his anterior paddles into a more *arm-like* limb. As he practised the habit of throwing his body more and more, together with a new and necessary act of climbing upon rocks and low hillocks, and this in a dry air and strong sunlight, he developed a greater growth of his digital phalanges, as well as a finer and more flexible external integument. This would gradually increase in succeeding and more favored individuals until a tegumentary brachial parachute was finally formed.

In the fossil bones of the pterodactyl that have been preserved to us, we find that this increased development of the phalangeal bones has actually taken place. It has reached a degree of extraordinary growth in the fifth digital phalanx, which grew to a length sufficient to form the frame of a large *bat-like* wing.

From the anatomical structure of an animal we can learn its habits and modes of life. We know, therefore, that the unusual growth of the fifth digital phalanx, and a like unusual growth of the external integument, could not form a true wing capable of supporting the animal's body in aërial flight. A true wing needs the support of the humerus, the radius, and ulna to bear the muscular effort necessary in flying. The phalangeal bones play an unimportant part. In the pterodactyl the parachute of integument was supported almost wholly by the long slender fifth phalanx. It was then only a partial help to the animal to aid him in gliding through the air from slight elevations, as he threw himself upon the object of his attack. His ferocious nature would lead him, in his search for food, to

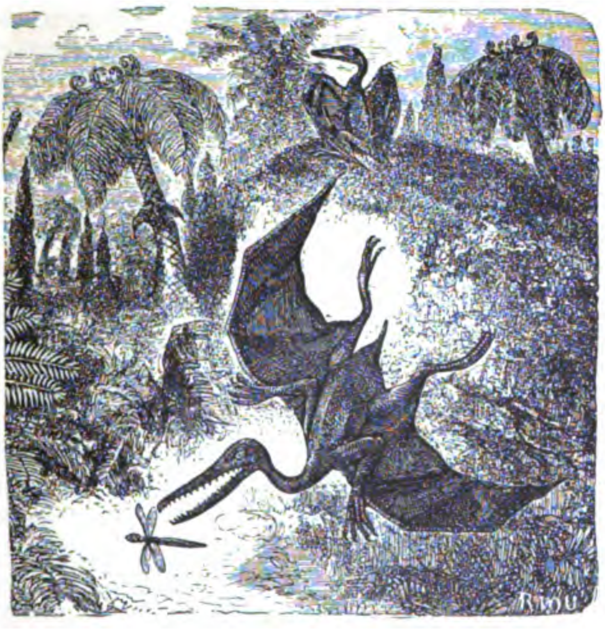


FIG. 46.—PTERODACTYL OF THE JURASSIC AGE.

practise this act of throwing his body more and more, and thus develop to greater perfection the bat-like tegumentary expansion that served as a partial wing. The habit of the pterodactyl of throwing himself upon his prey was a matter of necessity, for his tegumentary membrane acted only as a parachute and not as a wing.

It is extremely probable that the pterodactyl is the progenitor of the bats which were evolved in a later age. He has transmitted to them his tegumentary wing-membrane, as well as his rapacious habits. In the bats, however, all the digital phalanges have undergone an increased growth, and act as a supporting frame to the thin membranous wing. The bats fly with a quick intermittent motion, and not with the slower sweep of the birds. They use the thumb, which is not developed like the phalangeal rays, as a means of support in climbing or perching.

The pterodactyl must have used his wing-membrane in an intermittent manner, and it is probable that he transmitted this special movement to the modern bat.

A similar act of throwing the body upon its prey, such as we believe the pterodactyl to have had, has been transmitted to our own time, and is seen in the pelican *(Pelicanus onocrotalus)*. I have often watched these birds in Panama Bay. They seek their prey in the early morning. They fly leisurely in the air not far above the water, and when a fish is seen, they allow the wings to fall near their sides, and throw themselves headlong with a sudden plunge into the sea. In rising they beat the air violently with expanded wings until a sufficient impetus is acquired to buoy them away.

The pelican has a true wing, and is capable of true aërial flight.

As an example of the remarkable power possessed by a true wing in long-sustained aërial flight, may be mentioned the albatross *(Diomedia)*. While cruising in the South Atlantic Ocean, on the U. S. Ship *Ino*, along the coast of Eastern Patagonia and as far south as Cape Horn, I had an excellent opportunity of observing the extraordinary powers of flight of these interesting birds.

As they flew about the ship I selected certain birds that could be easily distinguished from the others about them by certain markings of color and by the tameness they show when they follow a vessel for any length of time, and then I carefully watched them as they wheeled and circled about the ship. As we were sailing about ten miles an hour, they must have at least gone five times that distance, for they flew round and round, then in advance of us, then far astern, but keeping generally quite near us. This would give them a flight of fifty miles an hour, which I observed for twelve hours of daylight. This was accomplished with little apparent effort, yet the bird from time to time beat the air with his wings to maintain his speed and elevation. They had a habit, when flying close to the ship, of turning the head sidewise to look at us. This was owing to the fact that in *birds* the optic nerves cross each other. The nerve from the right optic tubercle going to the left eye, and the nerve from the left optic tubercle going to the right eye. They cannot look directly ahead owing to this decussation of the optic nerves and to the lateral situation of the eye in the head. I always noticed that when the albatross turned his head sidewise in this manner he seemed to lose speed a little, and was compelled to flap his wings slightly in order to regain it. This side movement of the head, together with the friction of the air, tended to retard somewhat his aërial motion.

A few bones of a small and peculiar animal have been found in Europe, and with these a new and singular form of animal life has been reconstructed. This creature, which attained only to the size of a large pigeon or common hen, has been named the **Ramphorynchus.**

Like the pterodactyl, it had a remarkable development of the fifth anterior digital phalanx, which stood at a right angle to the body when the animal crawled upon the ground. The wing-like expansion of the tegumentary membrane was smaller and less completely developed than in the pterodactyl. The anterior and posterior limbs were long and slender, and terminated in three claw-like toes. As *all* animals have *five* phalangeal rays or digits, when they are not seen externally, as in the ramphorynchus, we may conclude that the remaining ones were either rudimentary or concealed within the external integument. They are always present, either as splint or rudimentary bones, or are consolidated with the others.

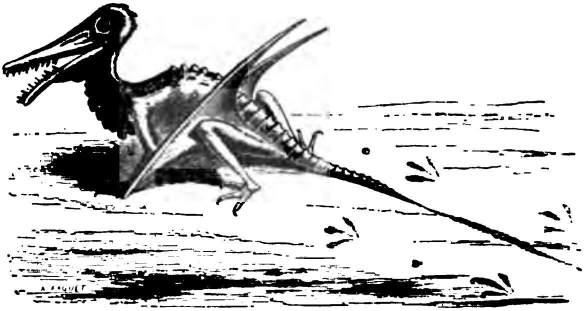


FIG. 47.—RAMPHORYNCHUS.

In Fig. 47 we have an outline of this animal. The body is decidedly saurian in character, as well as the head and long powerful jaws, with their sharp teeth, which betray at once its predatory and rapacious nature. The evolution of this animal has followed along the same line, and has been influenced by the same causes that led to the development of the pterodactyl from the plesiosaurus.

It seems quite reasonable to believe that this animal did not progress very far upon the path of evolution, and in the course of time became extinct. Neither was he the progenitor of any succeeding forms.

It would seem that an animal so handicapped by such a development of the phalangeal bone would not be well fitted to propagate himself in the midst of dangerous enemies, and would therefore early succumb in the great struggle for existence.

Another species of reptile appeared in the Jurassic period. This was the formidable **Teleosaurus,** which bore a striking anatomical resemblance to the modern gavial of India as did the nothosaurus of the Triassic period to the modern crocodile and alligator. The teleosaurus was considerably in advance, in his anatomical and physiological development, of the nothosaurus, and was without doubt his successor in the scale of evolution. His premaxillary bones, his more complete dentition, his more highly developed legs, and his intricate cuirass-like integument, all denote an advance in the scale of animal life. While the teleosaurus, like all the ancient saurians, could live in the water and lead a double or amphibious life, his structure shows that he preferred a terrestrial mode of existence. His powerful tail was well adapted for marine locomotion, but his tracks in the sand show that his feet were also well adapted for free movements on land. The bones of his legs show also a higher development of the femur, tibia, and fibula of the posterior limbs, and of the humerus, radius, and ulna of the anterior limbs, than did those of the nothosaurus.

His armor-like integument developed as a result of his amphibious existence. A constant change from land to water, and the intense activity of those animals leading to greater nutrition of the external parts through an increased capillary circulation, would in the course of time lead to greater growth of the external integument.

The stronger individuals would transmit their qualities to their successors, and thus powerfully aid in the perpetuation and continued growth of this special tegumentous covering.

In Fig. 48 we have a good view of this animal as he appeared in that long-past age.

The great saurians thus far described were either swimming or amphibious, lizard-like animals of large size and of a ferocious and predatory nature, the true characteristics of that special form of reptilian life. The later forms, notably the teleosaurus, lived and moved upon the land as well as in the water, but all depended upon the sea for their subsistence, and all found a congenial habitat in the shallow seas and on the great marshes of the Triassic and Jurassic periods. While isolated regions of dry and elevated land were seen here and there, yet the vast areas of what now constitutes North and South America, and of Europe, Asia, Africa, and Australia, all of which were then continuous and connected over the whole of the north polar region, were either partially submerged or existed as wide-spreading level marshes or lowlands.

We may inquire what spectacle the surface of the earth presented at the close of the Jurassic period, and the reason of the inquiry is that no new forms of true saurian life of any importance appeared after that period. In the following geological division of time—

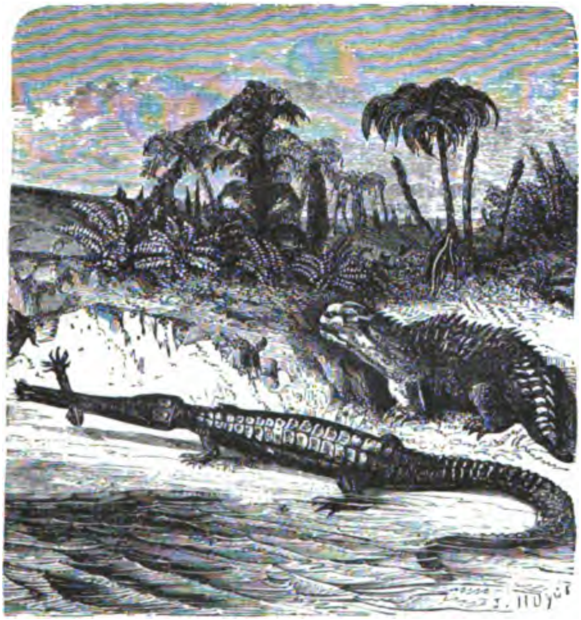


FIG. 48.—TELEOSAURUS, OF THE JURASSIC AGE.

the Cretaceous period—a more advanced form of life appeared—namely, the herbivorous saurians. Geology has given us an exact answer to our query. As the Jurassic period drew near its close the surface of the earth presented a view of partially formed continents more or less connected and encompassed by seas of fresh water, which were shallow near the shores but of a remarkably uniform and stable depth at a distance from the continental shore-lines. The sea and the air were equably and universally warm and quiescent. The whole surface of the earth enjoyed a uniformly warm temperature. The sun shone upon the earth through a clear air, and through his influence of evaporation and precipitation of moisture copious rains fell in showers over the land. Few if any rivers existed, certainly none of any considerable size. Great forests covering extensive tracts grew luxuriantly. Most of the trees were of a species unknown in our times. Rising above the great marsh and forest levels were the Laurentian Hills, already old, and the younger Black Hills of Dakota—islands in the midst of the sea. Isolated elevations occurred here and there in Europe, as the Jura Mountains in Switzerland, but none of the *great* mountain chains had raised their towering summits above the monotonous level. The Himalayas, the Andes, and our own Rocky Mountains were then unborn.

Great reptiles, fierce and rapacious, were the undisputed masters of the sea, and swarmed in great numbers along the extensive coasts.

The ammonite and the belemnite shared the seas with the great saurians. These fierce univalves with their long powerful tentacles presented a threatening aspect as they ranged the coasts in pursuit of their prey. A vast number of mollusks, both bivalves and univalves, were to be found along the silent shores of that ancient world.

Crustaceans not unlike our modern lobster inhabited watery nooks and caves on those ancient coasts, and a few insects made their uncertain way in the air. No bright-colored and fragrant flowers ornamented the sombre landscape, and birds were then unknown.

Such was the aspect of the earth at that time, could we have been there and have seen it with our material eyes. Yet viewing it with a retrospective mental glance we can see it just as clearly and as accurately as though we had actually visited it in person and beheld the strange panorama as it stretched away before our wondering gaze.

In the Triassic period and far into the Jurassic the great marine carnivorous saurians had risen to the highest point of their development. That geological age has been well called the age of reptiles. Those fierce and mighty forms of reptilian life would appear strange to our eyes could we see them to-day. We might be inclined to call them monsters, did we not remember that they were examples of a tremendous exuberance of the development of that special form of animal life under exceedingly favoring conditions.

At the close of the Jurassic period, however, these animals began to decline, until in a then not far distant age they finally disappeared. As their evolution and development from a preceding lower form of life was the subject of our study, it may be interesting to know why they disappeared, and why they did not continue on in their strong and vigorous life and so perpetuate themselves to our own time. We have already said that certain forms of life followed out certain lines of development through great intervals of time, and so perpetuated their species to modern times with but slight changes or variations of form.

It is undoubtedly true that the nothosaurus and the teleosaurus, both true lizard-like, amphibious reptiles, have followed out long lines of development, and have transmitted themselves with some modifications to our own times, and have given to us as their successors the crocodile, the gavial, and the alligator, as well as the more diminutive land lizards.

The ichthyosaurus, the plesiosaurus, the labyrinthodon, the pterodactyl, the ramphorynchus, and some lesser important forms have been the progenitors of, and have transmitted some of their qualities to, other forms of animals, as we have already seen, and they, finding themselves surrounded by new conditions of life, assailed by newer and more active enemies, gradually suffered a decline which went on to ultimate extinction. In the Cretaceous period, the land underwent some changes of level, and of upheaval and submersion, which were unfavorable to the development or to even the continuance of reptile life, and so these extraordinary reptiles found themselves confronted with the sharp edge of new and hostile conditions that led to their final decay.

They arose in obedience to the advancing law of evolution, and having reached the climax of development, and fulfilled all its conditions, they succumbed, and were succeeded by animals more highly advanced in the great scale of life, and better fitted to continue the law of higher development.

As the Jurassic period drew near its close—an age so full of zoölogical interest, and an age that marked many changes in the earth's surface—the great marine saurians suffered so marked a decline that it was called the close of the age of reptiles.

Other reptilian forms appeared in the succeeding age which showed a considerable advance in development over those passing away. In the place of the marine carnivorous saurians then becoming extinct, appeared others wholly terrestrial in their habits and modes of life. They were *herbivorous* saurians, or a form of animal that was decidedly saurian in many of its characteristics, but still pointing upward to features that were strongly mammalian.

The progress of animal life was rapidly onward. It is a long stride from a marine saurian to a saurian wholly terrestrial, and the change required many ages for its accomplishment. The former is carnivorous, the latter herbivorous, but both retain the saurian ferocity of nature and predatory habits. The latter is of a more advanced type, and is a grade higher in the scale of life. He is also the progenitor of the marsupials, those intermediate links in the chain of evolution between the saurians and the mammalians.

The marsupial, in his turn, becomes the progenitor of the true mammal, and while none had then appeared, we may say that he stood, as it were, at the dawn of their existence, and foreshadowed their coming. He was the first of the warm-blooded animals, and brought forth the young alive, although only partially developed.

This was the beginning of *viviparous* propagation.

Hitherto all the fishes and reptiles had propagated their species by eggs. They were *oviparous* animals. The female produced the eggs, which were fecundated through the agency of the males, except in the earlier forms of animal life where both sexes were combined in the same individual.

CHAPTER VIII.

THE MESOZOIC AGE:—THE AGE OF REPTILES. THE CRETACEOUS PERIOD.

Decline of marine reptiles—Changes in the air and the earth—Change of flora—Palms—Oak—Maple—Beech—Poplar—Fruits—Hylæosaurus—Dinosaurs—Mosasaurs—Pterosaurus, or flying lizard—Iguanodon—Megalosaurus—Development of the sacrum and of the pelvis—The pelvic arch—Formation of acetabulum—Hamites—Perna mulleti—Scaphites—Crioceras—Ancyloceras—Sharks—Great continental archipelagoes—Observations on the extinction of saurian life—The earth as it then appeared—Odontornithes, or birds with teeth—Hesperornis—Ichthyornis—Ceratopsidæ—Triceratops flabellatus.

THE third subdivision of the Mesozoic age—namely, the *Cretaceous* period—followed the Jurassic in an orderly and sequential succession. Its special geological characteristic was the formation of *chalk* or carbonate of lime in vast beds, occurring principally in the State of Dakota to the eastward of the Black Hills, where they extend for a distance of four hundred miles along the Missouri River. These chalk beds are of moderate elevation, and were deposited in the warm, fresh seas of the lower Cretaceous period while the Black Hills, great isolated islands, stood like vast and silent sentinels over them. They were contemporaneous with the chalk deposits of England, where it formed great cliffs, which are so conspicuous an object on approaching them from the Channel or the German Ocean.

In the north of France the chalk deposits are also very extensive, where they form long and rounded ranges of hills, running parallel to each other, with regular intervening valleys. The railway from Havre to Paris pierces a number of these chalk ridges in succession, at nearly right angles to their trend.

Specimens of this chalk, which I procured from the sides of one of these tunnels, compared with specimens from near Dover, England, and from Dakota, show them all to be calcium carbonate, made up largely of minute marine mollusks. The cretaceous deposits occur also in Denmark and in Sicily, but are less extensive than in our country. In Fig. 49 is seen a specimen of chalk from France, magnified under the microscope, showing these minute shells.

Most of these mollusks are very minute in size; some of them are only composed of a single-celled calcareous shell, while others are of an exceedingly complex structure. All of them that I have examined under the microscope, with a sixth and tenth objective, are univalves, and every variety of these little shells has undoubtedly been secreted by the mantle of the animal. These univalve cephalopods and gasteropods of the microscopic world were identical in construction with the larger ones already studied. Many of them were chambered shells like the ammonites, some were pointed at the apex like the belemnites, and were no doubt minute tentacled cephalopods like them, having the same habits and modes of life on a smaller scale. These microscopical creatures presented a great diversity of shape, and followed the same law of development as their more formidable brethren. They were sufficiently numerous to form the vast chalk deposits already described in our own country and Europe. This is one of the first instances of the enormously prolific development of the lower and minute forms of life. Many millions of individuals are produced, while comparatively few reach mature development, or attain to even average longevity.

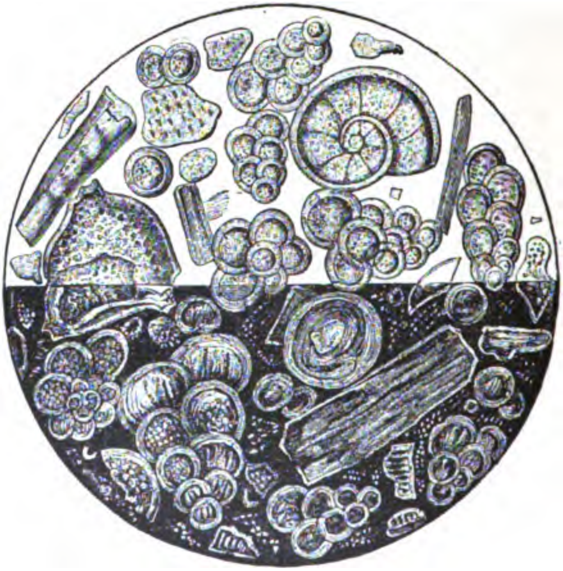


FIG. 49.—FOSSIL SHELLS FROM CHALK OF THE CRETACEOUS PERIOD.

We have seen that, as the Jurassic period closed, the age of true reptiles closed with it. No new ***marine*** reptilian forms appeared. Those then existing reached the highest point in the period of their evolution and growth, and then began slowly to decline. With these changes in reptilian forms we also see that a marked change occurred in the flora of this epoch. Many of the older plants of the Carboniferous age began to pass away, and newer species, many of them destined to survive to our own time, appeared in their stead. The Carboniferous forests were composed of porous, cellular, and rapidly growing trees. These were being gradually replaced by those of a slower growth and more compact structure.

The great modern group of trees belonging to the order of the **Angiosperms,** or those having the seed enclosed in a *pericarp* or external covering, made their appearance.

This interesting group comprises trees of modern times with which our eyes are familiar, and which adorn our landscapes. The beautiful oak, the maple and willow, poplar, beech, and some kinds of fruit-trees, are well known examples. These forms of plant life, so different in texture from those that preceded them in the earlier ages, were the result of a greater amount of sunlight, a dryer and clearer atmosphere, and a dryer and more elevated soil. These were powerful factors in producing a more closely organized woody fibre, and caused a slower growth and a more compact arrangement of the cells forming the ligneous tissues.

Meteorological and terrestrial changes cause a change of form and texture in plant life. In the Carboniferous period the land was low and swampy; the air was cloudy, and contained a large amount of carbonic-acid gas. Rains fell in abundant showers, and the temperature was torrid. Under such conditions vegetation was stimulated to rapid growth, and rapidly growing plants are usually cellular and porous in texture. The trees of that epoch were of that loose texture and porous character. But in the Cretaceous period the terrestrial and atmospheric conditions were changed. The air was clearer and less humid. A warm uniform temperature still extended over the whole of the earth's surface. The copious rains continued, stimulated by the evaporating effect of warm sunlight, and the ground was dryer and less swampy.

Plant growth was less energetic, and a slower growth means a more dense and compact texture of woody tissue. As the plant grew more slowly, and in a dryer soil and clearer atmosphere, the plant-cells were more densely packed, and this formed a ligneous fibre of a closer grain and a more durable character.

In the Cretaceous period there appeared besides the trees just described the first of the *true palms.*

We have already seen that the arborescent ferns of the Carboniferous period were strikingly like palms in general appearance, and there can be little doubt that the tree ferns of that epoch became the palms of the Cretaceous period. In Fig. 50 we see these fossil palms restored; and the same variety of palm tree has come down to our own time.

If the palms of that age approximate to those of our own era, we cannot say the same of the animal world. The earth was still tenanted by reptiles, those great marine saurians of carnivorous habits that dwelt in the sea and preyed upon other marine animals. In the course of time, however, some of them suffered a change in configuration and mode of life, which change was induced by an individual now and then finding a congenial habitat upon the dry land, and slowly, little by little, he acquired a habit of feeding upon the rich and tender foliage that grew so abundantly everywhere about him. Such a change in the mode of life

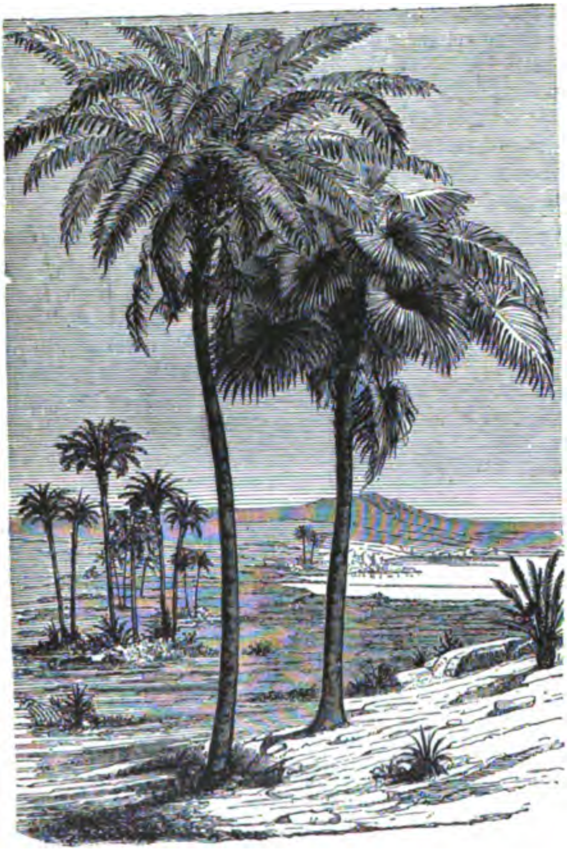


FIG. 50.—FOSSIL PALMS OF THE CRETACEOUS PERIOD.

of these great animals, however gradual, would be transmitted to their successors, and after a long period of time induced changes of bodily structure of an anatomical and physiological character. The method of feeding upon nutritious foliage easily obtained, tended through disuse to shorten the long formidable jaw that was formerly so necessary to the needs of a marine carnivorous reptile who was compelled to maintain a fierce struggle for existence against powerful and dangerous rivals. The shortened jaw also required the development of a different growth of the teeth, better adapted to the mastication of vegetable food.

As the reptile began his new mode of life by moving about on the land in search of his new kind of food, his limbs were from necessity stimulated to greater and more perfect growth. Ample food causes ample nutrition and a richer supply of nourishing blood. The exercise of moving over the land induces a determination of blood to the parts thus exercised, and the deposit of cellular materials fitted to make bone and muscle. Hence the imperfect legs of the nothosaurus would under the influences of these new conditions become the more perfect legs of a more advanced type of animal life that made its appearance in the Cretaceous period—namely, the **Hylæosaurus.**

In Fig. 51 we see this animal restored.

The bones of this animal have been found in several localities in our own country and in Europe, and from them the form has been restored with as much fidelity as though the creature stood before us to-day.

It will be seen that the hylæosaurus retains the scaly, pachydermatous integument and powerful tail of the marine saurians, showing he is a saurian himself, but a long step in advance of his predecessors.

His legs have undergone a change of growth and are more highly developed. The bones are more like those of a locomotory than a swimming limb, and although still retaining reptilian characters, are more free in their movements, permitting the animal to walk about with ease on dry land.

It will be noticed that the long, pointed, and prehensile jaw and sharp conical teeth of the marine reptiles have become changed to the shorter and more rounded maxillæ of a land animal. As he is a vegetable feeder he no longer has need to seize and hold his prey with his elongated jaws and formidable teeth, and so they undergo a change and become atrophied, and are replaced with a shorter jaw and teeth fitted for an herbaceous diet.

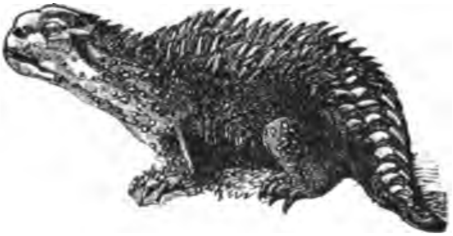


FIG. 51.—HYLÆOSAURUS OF THE CRETACEOUS PERIOD.

The hylæosaurus is an herbivorous reptile subsisting wholly upon vegetable food. Like the marine saurians, he propagates himself by eggs, for he, like them, is an oviparous animal. His higher anatomical structure and more complete osseous development plainly foreshadows a type of animal of a more special organization in the scale of evolution. It is very probable that he was the progenitor of some of the great land carnivoræ that appeared in a subsequent epoch.

At this period of the earth's history some of the great saurians found a more congenial habitat in regions that are now known as Europe and Asia, while others lived by preference in what has since become America. The ichthyosaurus and the plesiosaurus flourished more abundantly in European regions. The **Dinosaurs** found congenial conditions of life in our own country, where during the ages of the Cretaceous period they reached the highest point of their development. They were truly termed the "terrible lizard," and they must have been a formidable foe to other and more defenceless animal forms. The dinosaurs are of especial interest to the anatomist. They were of large size, and all of them walked on their posterior limbs, seldom bringing the anterior limbs to the ground. Although they were reptiles they show some affinities to birds which appeared in a later age. It is probable also that they were the progenitors of the marsupials.

During the Cretaceous period a great saurian form developed rapidly and attained enormous proportions. This was the **Mosasaurus**. He was a *marine* saurian, and while he sprang without doubt from the nothosaurus, he did not reach his highest point of development until the Cretaceous period.

In the great inland Cretaceous sea, before the Rocky Mountains were lifted above the water level, this ferocious monster reigned supreme. He reached a length of sixty feet, and skeletons of this size have been found in our Western country. The long ages of the Cretaceous period gave him ample time to develop to this great size. As this inland sea became slowly filled up, and subsequently elevated into mountain chains, the mosasaurus found himself confronted with new conditions of life that led to his final extinction. He lived and died solely in our own country. He was a swimming lizard with four well developed paddles, and was therefore a wholly *marine* animal.

The **Pterosaurus**, or flying lizard, was one of the most interesting reptiles of the Cretaceous period. He differed essentially from the pterodactyl, which flourished almost exclusively in European regions, in the entire absence of teeth. It is very probable that the pterosaurus descended from the earlier pterodactyl, and in the newer and more favorable conditions of the earth he easily developed to a greater size and more special organization. He had a wing membrane, but it was more perfectly developed, and hence he was able to fly with greater ease and precision. He was a veritable *dragon*, with a spread of wing of from ten to twenty-five feet. It is believed that the pterosaurus was the progenitor of some of the birds. As the Cretaceous period closed he became extinct, and left us his fossil remains in several localities of our Western country.

The Cretaceous period was rich in the great forms of animal life, and among them appeared that strange creature known as the **Iguanodon,** Fig. 52. This animal was an herbivorous saurian, and one of the largest and most formidable of all of those ancient monsters. While he differed in many important respects from all other saurians, he was, nevertheless, decidedly reptilian in character.

His fossil bones that have been preserved to us show that he was an animal of great size, with a length of body of probably not less than twenty feet, exclusive of his long pointed, tapering tail.

His legs were shorter than those of the hylæosaurus and belonged more to the reptile than the mammal, yet he was terrestrial in his habits and could move about

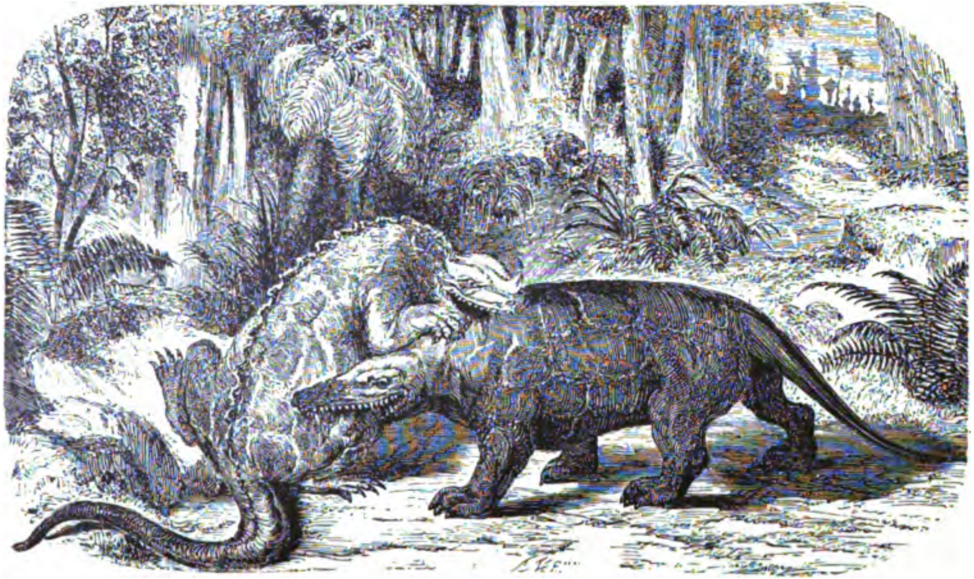


FIG. 52.—IGUANODON AND MEGALOSAURUS OF THE CRETACEOUS PERIOD.

with ease upon the land. His head and jaws were short and rounded, and his teeth were fitted for a diet of vegetable matter. Upon his nose he carried a horn of osseous construction which grew out of his pre-maxillary bone. He was a *pachyderm.*

It would seem that an animal of the form of the iguanodon was an instance of what may be termed the divergence of form from other animals having in the first instance similar qualities. The hylæosaurus and the iguanodon undoubtedly sprang from a common saurian stock, and throughout their entire career preserve reptilian characters. But in the course of time they show points of divergence, although both had a similar environment. Slight causes would induce slight changes, and in time these changes necessarily led to considerable differences, both in outward form and habits. These differences again would be transmitted to their offspring, and in this way an individual with new characteristics would be formed.

Another divergence of reptilian form may be seen in the **Megalosaurus,** Fig. 52, which also flourished in the Cretaceous period. In this animal, still a reptile, we see the reptilian jaws and teeth, showing it to be a carnivorous saurian, although living exclusively upon the land. We see the reptilian-like head of the nothosaurus, but its existence on dry land has caused a rapid development of the body towards a mammalian type. Its limbs are passing beyond the reptile stage, and owing to its eager and active life as a carnivora they are developing into a true leg fitted for active locomotion on land.

Habits of life determine to a considerable extent the development of limbs, and the special development of limbs often determines habits of life. The megalosaurus, although a reptile, by his carnivorous instincts is led to pursue his prey, and this requires activity of movement. This activity leads to a more complete development of the bones of the legs through increased nutrition, as we have already seen, and as a result we have an increased growth of the humerus, radius, ulna, and bones of the foot in the anterior limbs, and of the femur, tibia, fibula, and bones of the foot in the posterior limbs. Disuse of the tail leads to its atrophy, and in this animal the caudal vertebræ are but slightly developed. The pachydermatous integument is disposed in rhomboidal plates, and we here see the foreshadowing of the rhinoceros and the hippopotamus of modern times.

In Fig. 52 we have a restored view of the iguanodon and the megalosaurus.

In these two saurians, and the hylæosaurus also of the Chalk era, we have a considerable advance in their special anatomy over those saurians of a previous age.

As they were terrestrial saurians, and moved about on the land, the loose articulation of the posterior limbs with the vertebral column, which was all that was necessary in a swimming saurian, was no longer adequate for the higher grade of movement of these animals. Hence a change occurred. At the point of contact of the head of the femur with the posterior part of the vertebral column the increased strain on the vertebræ induced by the efforts of walking brought about an increase of growth of those bones, and in time they *coalesced* and formed the *sacrum*. Usually five of these vertebræ united in this way, and formed the base or keystone of the sacrum, which was one of the earliest processes in the formation of a *pelvis*. As the posterior limbs acquired a greater mobility in locomotion, the head of the femur would require a firm point of support, and in its upward thrust against the now consolidated lumbar vertebræ it would form for itself in the bone a cavity in which it could freely move in its efforts of walking. In this way the first *acetabulum* would be formed, a cavity in the pelvic bone that has been a permanent mammalian feature ever since.

As these animals continued to advance in development, and as their terrestrial mode of life led them to freer and more energetic movements, the solidified bones of the sacrum would extend new points of ossification, and project on either side until these projections gradually united in the anterior median line, and formed the *pelvic arch*. We have then, in these animals, the first of the series having a true *pelvis*. This structure places them far in advance of any previous animal organism, and leads rapidly to the next grade in the upward series in animal evolution—namely, the marsupials.

The Cretaceous period closed with a vast number of living organisms swarming in its congenial seas, or revelling upon its luxuriant land.

The ammonites, which in their earliest times were modest in size, now grew to enormous proportions under the favoring conditions of the Cretaceous oceans. They have been found in several localities in our own country, and also in Europe, measuring three feet in diameter. These animals possessed enormous power and vitality to enable them to secrete so great a quantity of lime and elaborate it into a shell of such massive and complex proportions.

A singular species of cephalopod called **Hamites,** from *hamus* a hook, has been found in considerable numbers in the Cretaceous deposits. This animal, which was a predaceous and tentacled mollusk, attained a large size, and its shells have been found over quite extended areas both here and in Europe.

It seems to be another instance of the divergence of form of other animal organisms. It is more elaborate in its shell markings than the belemnites, and less complex and convoluted in its structure than the ammonites.

Like them, it was a marine cephalopod, and its structure shows that it must have been armed with muscular tentacles, and hence was of a predatory nature. It has been found from four to six feet in length, in extreme cases, but most of them are smaller and partially coiled, and covered on its peripheral aspect with semicircular rounded ridges of shell, which were secreted by the mantle of the animal. In Fig. 53 we see the shell of one of these creatures.

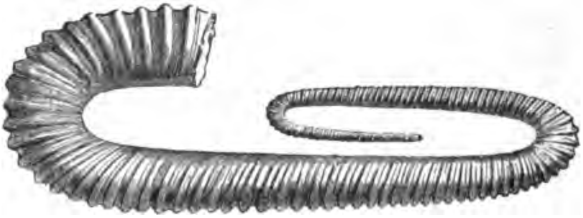


FIG. 53.—HAMITES OF THE CRETACEOUS PERIOD.
ONE THIRD SIZE.

A great number of mollusks were in existence in the Cretaceous period. Among those most important were the **Perna mulleti**, a large and complicated bivalve, which was so plentiful that the fossil shells have formed extensive beds.

The **Scaphites**, or boat-shaped shells, were also very abundant.

The **Crioceras** and the **Ancyloceras** were somewhat club-shaped, and resembled the hamites in being partially coiled and having spiral ridges. These are no doubt similar to the ammonites, except they are only partially coiled.

The great profusion of forms that existed show how prolific molluscan life was in the favorable conditions that prevailed at that time.

Many sharks, and a considerable number of fishes, swarmed in the Cretaceous seas, as well as crustaceans and crinoids.

It is believed by geologists that in the Mesozoic era the dry land of North America and a large part of South America existed very nearly as it does now, with the exception of the Andes and Rocky Mountains, which were uplifted at a later period.

The Laurentian Hills stood firm and unchanged, while away to the north and thence over the great areas now known as Europe, Asia, Africa, and Australia stretched one vast archipelago, which has since undergone many violent changes of uplift and submergence, until the great continents of the Eastern Hemisphere were finally shaped as they exist to-day. There is no doubt that from the very first, when the low line of the Laurentian Hills was first raised above the surface of the universal sea, the general outlines of all the continents were formed, and that as points of land were uplifted here and there, forming the great Arctic and European archipelagoes, the general configuration of the continents lay superficially under water, and over them were fresh, shallow, and quiet seas.

Beyond the coast boundaries proper, which in some localities were covered with water of superficial depth, lay the *deep oceans*, which have remained permanent and practically unchanged through all the ages until our own time. The permanence and stability of oceans is one of the most striking facts in all the history of geology. The deep ocean bed has undergone but little change of level during all the lapse of the ages.

As the Cretaceous period drew near its close, the earth presented a scene that would have appeared strange to our eyes. The sea swarmed with sharks, fishes, and reptiles of monstrous size. The mosasaurus, nothosaurus, teleosaurus, plesiosaurus, and ichthyosaurus were masters of the sea. Ammonites, belemnites, and a host of other molluscan shapes lived also in its depths.

On the land was seen the graceful palm, and vast forests of luxuriant trees stretched away in magnificent vistas. The uncouth hylæosaurus, the megalosaurus, iguanodon, and the dinosaurus savagely disputed possession of the earth with some lesser forms and with each other. The pterodactyl and the ramphorynchus, with unsteady flight, preyed upon the abundant insect life whose ceaseless activity broke the stillness of those ancient forests.

The huge pterosaurus—that great flying dragon—exerted a reign of terror by his fierce and rapacious nature.

A few birds flew silently among the forest trees, but none were of bright plumage and pleasant song that so cheerily greet us in our own times.

Changes in the surface of the land slowly occurred. Extensive areas were raised above the surface of the shallow sea, and islands were joined together, forming greater tracts of dry land.

These terrestrial changes ultimately proved fatal to the continuance of saurian life, and at the close of the Cretaceous era we find these great animal forms slowly disappearing, until they became wholly extinct. As dry land was gradually extended in area by submarine upheaval, and as islands coalesced and became a part of the continent, a disturbance ensued that made a continuance of reptilian life impossible, and the shallow seas and marshes, covered with water of inconsiderable depth, once their favorite and congenial habitat, were changed into dry land, and made an enduring sepulchre for their bones.

During the later ages of the Cretaceous period we find two new forms of animal life that are very bird-like in appearance. They are known as the **Odontornithes,** or birds with teeth; one special form has been called **Hesperornis,** and another **Ichthyornis.**

Hesperornis was a bird-like animal of large size—more than six feet in length—of aquatic habits, and had a row of sharp-pointed teeth set in grooves in the upper and lower jaw. The wings were rudimentary and useless for purposes of flight. The legs were long and powerful, and were adapted for wading or for rapid motion on the land. It was, therefore, a struthious bird, and was a swimming ostrich having carnivorous habits and modes of life that were saurian in character.

Ichthyornis was a smaller bird-like animal with a more completely developed wing, and doubtless had the power, to some extent, of aërial flight. Its sharp teeth were set in sockets, and the vertebræ were bi-concave like those of fishes and a few reptiles. There were several other varieties of Cretaceous bird-like animals, but hesperornis and ichthyornis were the most interesting and important.

These two bird-like animals had certain well-marked characters that were decidedly saurian, and there is reason to believe that they sprang from a single ancestor, the dinosaur, an animal which, as we have seen, walked upon its hind-legs almost exclusively. In the course of time the dinosaur diverged along two closely parallel lines of development and gave rise finally to two new animals, differing from himself, but still retaining certain reptilian characters. These birds have been found almost exclusively in America, showing that here they found a congenial habitat for their special evolution and more or less complete development.

In the Upper Cretaceous strata, which lie along the eastern flank of the Rocky Mountains for a distance of eight hundred miles, have recently been found the fossil bones of a huge reptilian form, to which the name of **Ceratops** has been given. A number of fine specimens of this animal are now in the Yale Museum at New Haven, Conn. The enormous size this reptile attained, and the three massive bony horn cores that grew out of his immense skull, make him an object of special interest. He was a saurian and had all the saurian habits and modes of life, and his habitat was the great inland seas of the Upper Chalk era in what is now the Rocky Mountain region of our own country. During Tertiary times, when this region was uplifted to its present elevation, his bones were carried to where they are now found. We naturally inquire from what preceding lower form was this reptile, the *Triceratops flabellatus*, derived. It seems that all the probabilities point to the hylæosaurus of the Lower Cretaceous period as his progenitor. In the long intervening ages the necessary changes could easily take place to transmute the hylæosaurus to the ceratops. The ceratops undoubtedly developed his three horns from the necessities that arose to defend himself from active and dangerous enemies. Abundant food caused his rapid development, and geological changes caused his ultimate extinction.

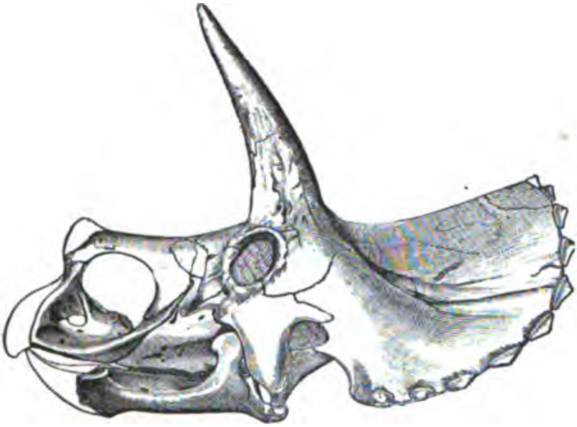


FIG. 54.—TRICERATOPS, SIDE VIEW.

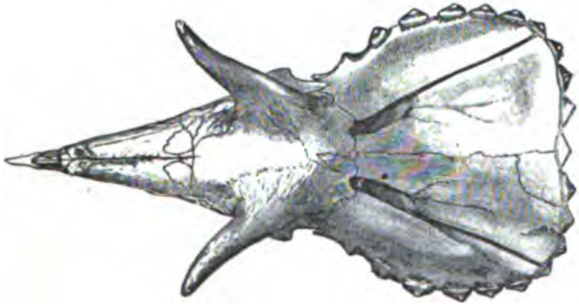


FIG. 54.—TRICERATOPS, UPPER VIEW. (MARSH.)

In Fig. 54 we see the skull of this strange animal.

CHAPTER IX.

THE CENOZOIC AGE:—THE TERTIARY PERIOD. THE AGE OF MAMMALS.

The Eocene period—Evolution of marsupials—Ovipara—Vivipara—Propagation of fishes and reptiles from eggs—The Graafian follicles—The ovaries—The oviducts—Change of physiological function of reptiles—Formation of the marsupium; of the milk gland—The secretion of milk—Paleotherium—Three toes—Anoplotherium—Two toes—The anoplotherium is the progenitor of the horse, lion, tiger, wolf, hyena—Xiphodon; he is the progenitor of the goat, sheep, llama, camel, giraffe—Lophiodon, titanothere, hyracothere, chereopotamus, whale, fossil tapir, deer, camel, horse-like animal, eohippus, orohippus, epihippus, peccary, rhinoceros, turtle, seal, walrus, serpent, titanophis — Evolution of birds; of feathers — Dinocerata; their development—Nummulites.

THE EOCENE PERIOD. EVOLUTION OF MAMMALS.

FOLLOWING the close of the Secondary period or Mesozoic age is the Cenozoic age, or as it is usually called by geologists, the Tertiary period.

In our own country the term Tertiary period is generally used. But in Europe this period has been subdivided into three lesser periods, which are very convenient designations when treating of the changes that have occurred in the long Tertiary age. They are as follows:

Eocene—Miocene—Pliocene.

The Tertiary period follows insensibly and orderly the close of the Cretaceous period, the last of the three subdivisions of the Mesozoic age. While the close of the Mesozoic age saw the decline of the great forms of saurian or reptile life, the Tertiary period saw the dawn of a new era—the appearance of true *mammalian life.*

The transition from a cold-blooded oviparous saurian to a warm-blooded viviparous mammal was not abrupt or sudden ; it was a slow and very gradual process of evolution, and required a long period of time for its accomplishment. Neither was the transition *direct* from a saurian to a mammal.

An intermediate form was evolved—namely, a *marsupial,* which was a semi-mammalian, and which brought forth its young alive but imperfectly developed, completing the process of development external to the parent's body in a pouch of abdominal integument, or marsupium, after its expulsion from the maternal body. A lowly form of marsupial appeared in the early Cretaceous period, and subsequently disappeared. It was an animal of small size, not unlike our modern opossum, but it stood as an intermediary form between the great saurians then so abundant, and the mammals that became so numerous in the Tertiary age. It becomes an inquiry of the deepest interest to know how a saurian who propagates itself by eggs, brought to maturity external to its body, could give rise to an animal who could mature its young, even partially, *within its body,* and bring them forth alive. How, in fact, a vivipara could be evolved from an ovipara.

The process of reproduction of the fishes of the Devonian age, of the reptiles of the Mesozoic age, and the mammals of the Tertiary age, while varying in some of its details, is essentially the same. In each species of animal a female apparatus for the production of eggs or germs, and a male apparatus to fecundate or fertilize the eggs or germs, is absolutely necessary.

In fishes and reptiles the eggs are formed in the body of the female, in a set of organs called the *ovaries*.

These organs consist of a mass of vascular connective tissue inclosing numerous globular sacs or follicles, the Graafian follicles, and these form a constituent part of the ovary. Each follicle contains an egg, which varies in size and appearance in different species of fishes and reptiles, but which has the same essential characters, and is produced in the same way. The egg grows in the ovarian sac, and is subsequently separated from its attachments and thrown off, but until that time it is an element of the ovarian tissues, and is nourished by them.

While the *ovaries* form the essential part of the female generative apparatus, there are also accessory organs which take part in the process of generation. The most important of these are two symmetrical tubes or *oviducts*, destined to convey the eggs in safety from the ovaries to the external generative orifice.

In Fig. 55 we see these organs, which are essentially the same in fishes, reptiles, and even birds.

In fishes the ovaries undergo at certain seasons a periodical development. The eggs approach maturity, gradually distend the follicles until they rupture, and then pass into the oviducts, where they are conveyed to the external generative orifice, and are expelled into the water in some secluded and favorable situation. Here they are visited by the male, and are fecundated, and afterwards hatched by external warmth into young fishes.

In some of the modern fishes of a high grade of development, as the sharks and skates, and some others, an actual contact takes place between the sexes, and the fertilizing fluid of the male is introduced into the female generative passages. Thus the eggs are fecundated within the body of the female, and after expulsion are hatched into young in some favorable locality. This is true also of reptiles. These animals lay their eggs upon the ground immediately after fecundation has taken place in the female generative passages, and incubation then goes on to its completion. In the great herbivorous land saurians, as the iguanodon, the dinosaurs, the hylæosaurus, and the megalosaurus, the eggs, which are fecundated within the body of the female by the sexual congress of the male, are deposited in some safe spot upon the land, where, under the influence of external heat, incubation proceeds, and the young reptiles finally come forth.

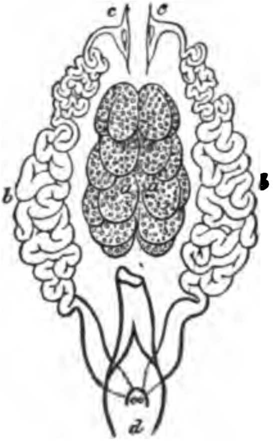


FIG. 55.—OVIDUCTS OF FISHES, REPTILES, AND BIRDS.

As these land saurians advanced to a higher plane of development, the influence of dry air and strong sunlight, as well as an abundant supply of nutritious food, caused them to gradually grow more active and warmer-blooded through more perfect pulmonary respiration. At the same time, the pachydermatous skin tended to become softer and less rugous. The individuals upon whom these influences acted most powerfully by preference consorted more and more together, as these new qualities would make the possessors more agreeable to each other, and thus by natural and unconscious selection, which is a most potent factor in inducing anatomical changes, they would transmit these new and higher qualities to the most favored successors, until they reached a much higher level in the development of special physiological functions.

These higher physiological functions consisted in producing the young from the egg while it was still within the generative organs of the female.

We have said above that in reptiles the egg was fecundated in the body of the female by direct contact with the male, and that immediately after fecundation the egg was deposited in some favorable locality, where it was incubated, and the young brought forth by the aid of external warmth.

This is true also of all birds.

If, after fecundation, the egg could remain for a time either in the generative passages of the reptile or the bird, the heat of the body would hatch the egg, and the young reptile or bird be born alive. But in neither of these animals could this occur, for the physiological functions of each demanded that the egg be expelled from the body before incubation took place.

As the more favored saurians advanced to a higher degree of development, their physiological functions of generation also advanced, until a point was reached where the female could retain the fecundated egg within her body until the young was hatched, and then, by a muscular expulsive effort, she could bring forth her young alive, although in a state of only *partial* development.

This partial development of her young at birth was owing to the fact that a true *uterus* did not then exist. The egg passed through its incubatory changes in the *cloaca* of the female, which afterwards developed in the higher mammals into the uterus or womb.

In this way the first of the marsupials was undoubtedly evolved from one of the higher and more perfectly developed saurians (or probably from the dinosaurus), through an advance of physiological function.

As the newly born young marsupial was only partially developed, the mother would instinctively seek to protect her offspring, and this she would naturally do by bringing it close to her own body. As the little creature nestled to its mother for protection and warmth, the latter would favor its efforts, until by and by the abdominal integument would partly close around it, and as this process was continually repeated and transmitted to others, the protective integument would ultimately form a distended sac, and this in the course of time would form a permanent abdominal pouch or *marsupium.*

At the same time, this warm-blooded mother with the abdominal marsupium, in which she shielded her young, would also seek to nourish it, and so bring it to full maturity. How could she accomplish this object?

The young and doubtless greedy marsupial would naturally seek to find something with which to satisfy its hunger. As would be most natural, it would use its mouth and lay hold of the maternal integument nearest to it—namely, that of the abdomen—and endeavor to draw some nourishment from it. Under the peculiar excitement and stimulus of the act of suction upon these tissues, a greater quantity of blood would be determined to the part, and an increased growth of loose connective tissue be the result. Under continued stimulation, this tissue by the greater proliferation of cell material would form a *gland*, and this, through the peculiar influence of gland-tissue action, would cause a secretion of lactiferous fluid or *milk*. It is well known that prolonged suction will induce a secretion of milk in a young and unimpregnated female, in whom the breasts are but slightly developed, and the same thing will occur in *man*, in whom the mammary tissues are also slightly developed, and are not intended for the secretion of lactiferous fluid. It is true that in this case the mammary tissue already existed in a dormant state, and was ready to enter into activity under a proper stimulus, while in the early marsupials no mammary tissue existed at all.

It appeared, however, under the special needs of the case, induced by the special act of prolonged suction.

In this simple way, then, the first of the true *mammalia* sprang into existence through the evolution of the marsupials from the saurians.

The act of bringing forth the young alive from the generative organs of the female, and the secretion of milk from the mammary gland to nourish the young in its helpless state of infancy, was the *greatest upward step* in the evolution of the important order of the mammalia that appeared in the Tertiary age, and has continued uninterruptedly to our own time. This change has been extremely slow, and has required many ages for its fulfilment.

The earliest marsupials seem to have disappeared in the last of the Cretaceous period, and reappeared in the Tertiary. It is more probable that they did not disappear at all, after their evolution, but were few in number, and easily lost sight of. An animal so difficult of reconstruction could easily escape the observations of geologists and zoölogists. It is extremely probable that when our own country is more carefully studied many remains will be found that are unknown at present.

The **Opossum,** a native of our own country, still exists, and the **Kangaroo** is still to be found in Australia.

I am inclined to believe that this latter animal appeared in the early Tertiary age, when Australia was connected with the great archipelago of the north, or the stretch of land that now forms the great continents; not that he appeared solely in Australia, for he might have appeared much farther north, or at several points simultaneously, and in his migrations finally reached Australia, where he has remained ever since, owing to the isolation of that great island by the submergence of the land that formerly connected it with the continent of Asia. The evolution of the kangaroo, which I believe will be referred to the early Tertiary, or Eocene period, was, without doubt, from the dinosaurus of the late Cretaceous period. A study of this animal, whose fossil remains are preserved to us, will show how easily this change in his anatomical structure could occur to transmute him to the newer animal. The dinosaurus was an herbivorous saurian, living exclusively upon the land. He walked habitually upon his hind feet, and left what have been called "bird tracks" in the soft mud of that period. His successor, the kangaroo, who was slowly evolved from him, subsisted chiefly upon the shrubbery and foliage of the trees about him. In his efforts to reach the higher branches he naturally reared himself upon his posterior limbs, supporting himself in this new position by means of his powerful tail. He thus became a *tripod* animal, resting upon his two hinder limbs and his tail as a firm base. This upright position would enable him to browse with ease upon foliage that would lie beyond his reach if he remained in a horizontal plane. By degrees he would find this position both agreeable and convenient, and as he moved from place to place to feed upon fresher foliage, it would be easier for him to do so by a slight jump or spring than to go down upon all fours and then raise himself again. Such a series of movements, long continued, would induce important structural changes in his anatomy. The posterior limbs would grow longer, and become adapted for an upright position with the tail as an auxiliary support. The anterior limbs, no longer needed for locomotion, would atrophy, and by a special use would assume the character and function of a prehensile limb or paw. These changes in the external anatomical configuration of the animal, added to those of a physiological character, whereby the female was enabled to bring forth her young alive, and nourish them in infancy with a secretion of milk from her own breast, and protect them while helpless in a pouch of abdominal integument, mark a new era in the evolution of animal forms, and stand as the first of the true mammals.

The higher development of physiological function took place in some of the other herbivorous saurians in the Tertiary age. The megalosaurus, a pachydermatous saurian, underwent a change also in his reproductive functions and anatomical structure, and from him undoubtedly the **Paleotherium** was evolved. This new animal was an herbivorous pachyderm and a mammal. Its bones have been found in the western part of our country, but more plentifully near Paris.

The change from the megalosaurus to the paleotherium consisted in the teeth and jaws becoming fitted for a vegetable diet, and in this latter respect we see the first formation of a *prehensile lip*, which has since been continued in the modern pig, peccary, tapir, horse, and elephant.

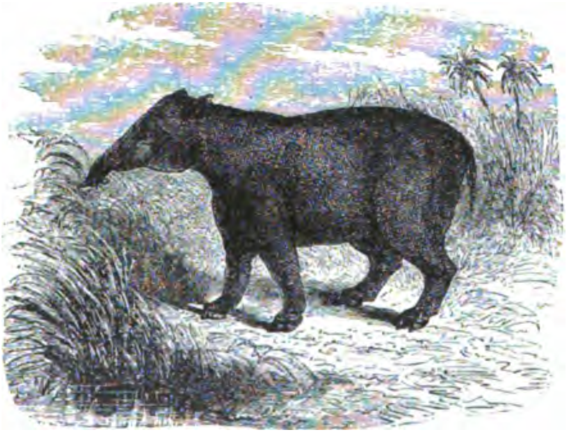


FIG. 56.—PALEOTHERIUM.

In Fig. 56 we see the paleotherium restored, and if we refer to Fig. 52 and compare him with the megalosaurus we shall find that he clearly shows an example of the divergence of form, of animal type, that was so striking a feature of the fauna of the Tertiary age.

The paleotherium is one of the first of the *Proboscidæ*, and foreshadows a long line of this particular type of animal—namely, the pig, peccary, tapir, horse, and elephant.

The long prehensile lip of the paleotherium was the result of a special anatomical growth in an animal having a short stout body and neck, with thickened and flattened cervical vertebræ, as the fossil bones of this creature have shown, with their long spinous processes, making a strong *nuchal* ligament necessary to support the large and heavy head. Such an animal would find some difficulty in bringing the mouth close to the ground for the purposes of feeding, and consequently he would freely use his lips to assist in bringing his food within reach of his teeth. Such an act constantly repeated would cause a greater degree of cell-growth and a greater formation of muscular extensible tissue, until a *proboscis* or elongated lip was finally formed. This same process of anatomical development is seen in the modern tapir, an animal closely resembling the extinct paleotherium, and was evolved from it. In the mastodon and the dinotherium the lip was extended into a *trunk*, and the elephant of our day has this trunk carried to a high degree of development.

If the paleotherium enjoyed a well organized prehensile lip to assist him to more easily gather subsistence, he did not have a well developed superior maxilla. In the skull of this animal, seen in our museums, it will be noticed that the nasal and pre-maxillary bones are imperfect and almost wanting. As the muscular lip was developed and employed to bring within reach his food, he did not need to seize it with his teeth, nor to use them for the purpose of grazing, hence in this animal the incisors and pre-maxillary bones were rudimentary. There can scarcely be a doubt that the paleotherium was the progenitor of all the proboscidæ that came after him.

There is reason to believe that the earlier forms of the paleotherium were small in size, and that as his evolution progressed, his better and more vigorous qualities were transmitted to his successors, until he reached his fullest development.

He belongs to the Eocene period, and in Europe he seems to have found an agreeable abode near Paris, where his fossil bones have been abundantly found. He loved fresh water, and was a vegetable feeder, and possessed a quiet and peaceful disposition, as his structure, dentition, and prehensile lip abundantly testify. Naturalists have found several varieties of paleotherium, showing that even at that early era animal forms evinced a strong tendency to diverge into newer and different types.

Another instance of the divergence of animal forms from a few simpler stocks, is the **Anoplotherium.** In this Eocene mammal now extinct we observe a considerable advance in the scale of evolution.

From what animal was the anoplotherium derived? It is a fact as well known as any fact in geology itself, that at the opening of the Tertiary period there were comparatively few *land animals* in existence. Four *definite* forms are known to us, as we have already seen —namely, the dinosaurus, hylæosaurus, iguanodon, and the megalosaurus. There were some others besides, but they were more lowly organized, less ably fitted to propagate themselves, and thus more easily succumbed to destructive influences. So it is quite certain that the anoplotherium could not have been derived from any of the weaker forms. It would seem very probable, then, that he came from the same stock as the paleotherium, and was a strong instance of animal divergence and evolution from another and preceding form.

In Fig. 57 we see a contour of this animal restored by Cuvier.

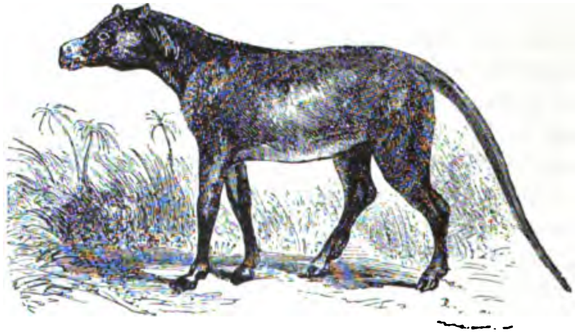


FIG. 57.—ANOPLOTHERIUM.

It shows him as he appeared in the Eocene period. If we compare this animal with the paleotherium, Fig. 56, while we see wide differences, we note also close resemblances, showing that both may have easily sprung from a common stock. The lip is less prehensile, though somewhat so; the dentition is similar, for he is an herbivora; the feet are *ungulated*, and have *two* toes, while the paleotherium has three; the legs are longer and more slender; and the tail is long, thick, and muscular, still retaining slightly saurian characters. It is believed that an animal with such an anatomical configuration must have had a soft skin, but owing to the uniformly equable temperature it must have been a smooth and *hairless* skin. The anoplotherium varied somewhat in size. The largest and best fossil specimens that have been found, showed a size about equal to that of a small *ass*. His slender limbs denote that he was quick and active, and could run with great speed, and he must have been of a rather peaceful disposition, as his dentition shows he possessed no weapons of offence. The crania that have been preserved to us show a fairly well developed brain cavity, and hence we conclude he had a well developed cerebrum, or brain, and the orbits and optic foramina prove that his visual apparatus was excellent. He was, then, an active, alert, intelligent, and peaceful animal. It is certain that such a mammal could easily diverge in form, in physiological function, and development, and under favoring circumstances and conditions, follow out on new lines of evolution, and give rise to other and newer animal forms, as the higher grades of herbivora—the horse, the zebra, and the ass, *Equidæ*, on one hand; and to some of the carnivora—the lion, the tiger, and the panther, *Felidæ;* or the dog and the wolf, *Canidæ*, on the other. and even to the hyena, *Hyenidæ*.

This view of the divergence of animal forms, which makes it possible for many to be derived from a few, is entirely logical and purely scientific. And this view seems the more probable when we recall the fact that the anatomical *osteology* of all these animals is strikingly alike. All the bones and their relative anatomical arrangement are nearly the same. The skeleton of a horse, zebra, lion, wolf, or hyena, bear a very close resemblance to one another; the especial points of difference lie in the teeth and terminations of the extremities. While a hoof and a claw at first sight seem to widely vary, it will be seen upon a closer study that both are but modifications of one and the same form.

The more superficial points of difference, as external shape, color, and markings of hair, disposition, and habits, are almost wholly determined by external environment, and, later, by climatic influences and geographical distribution.

The **Xiphodon** is another of the important mammals of the Eocene age. This pretty and graceful creature is a further instance of the divergence of animals from a common stock. His fossil remains have been found so well preserved that naturalists have been able to restore his form with great fidelity. Following out on a different line of evolution and development from the anoplotherium, and at first perhaps differing but little from him, in the course of ages the divergence slowly widened until a new form of animal life appeared.

Two ships sailing abeam in the same direction may not at first vary in their course at all, but after a time a slight deviation of the compass will occur, and this, ever so slight it may be, will in a very short time cause the vessels to separate until they are lost to each other's view.

Animals may likewise develop in parallel lines for a long time, and bear a strong similarity, but in the course of ages an organic, vital structure so plastic in its growth could not help undergoing some changes, and these, being continually transmitted to favored successors, would ultimately produce an individual entirely different from the primitive stock.

It is not necessary that we find all the bones of all the lines of animals that have undergone the transition changes from the early primitive form to the xiphodon. We know that such gradual changes must have occurred, and that they *did* occur is amply proved by the fact that the xiphodon lived, and his evolution from a lower form was the plain and necessary result of his delicate, plastic, organic structure undergoing anatomical and physiological changes induced by the law of higher growth and the influences exerted upon him by his surroundings and his instincts of preservation, propagation, and safety.

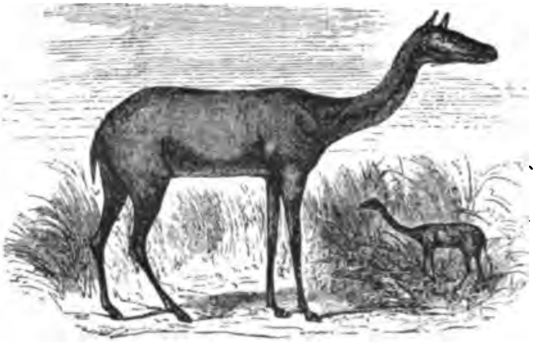


FIG. 58.—XIPHODON.

In Fig. 58 we see the form of the xiphodon. We notice in this animal certain peculiarities and characteristics that specially distinguish this species. He is an herbivora and subsists wholly upon vegetable food. As he is entirely without means of defence, and must seek safety in flight from his enemies, he has, as a result, developed a long and slender limb admirably adapted for rapid locomotion. Such long legs raise his body high above the ground, and as an absolute and necessary consequence his neck elongates to enable him to reach his mouth to the earth for food. This increased length of neck is not due to an additional number of cervical vertebræ, but to an increase in length of those already existing, and these, as we have seen, never exceed seven in number. His habit of feeding upon the foliage of shrubs and trees also exerts an influence in the elongated growth of the neck. • These two factors, then, determine his length of neck.

It will be easily seen that the xiphodon, with such a configuration and mode of life, may readily diverge and give rise to newer lines of animal forms. By a slight anatomical change he may give rise to forms that will ultimately evolve into the sheep, goat, llama, guanaco, camel, and giraffe, he standing as the common stock for all.

Or he may give rise to forms which will develop the whole order of deer—*Cervidæ.*

It needs but a slight change to develop a hump of adipose tissue upon his back to transform him into a camel, and under the influence of a dry, hot, and sandy soil his two-toed hoof would change to a two-toed, cushion-like, padded foot.

In the great number and variety of animal forms that appeared in the Tertiary and Post-Tertiary epochs we must always remember that changes of anatomy and of external characters and habits are easily and readily induced in vital organisms so extremely susceptible to the impress of surrounding influences. And these influences are manifold in their number and method of application. All the mutations of animal organisms have thus far been along lines of very close parallelism. While the anatomical and physiological divergences seem at first sight great, and when compared with simpler and earlier forms *are* great, yet when compared again with some of the later and more complex forms they are comparatively slight.

In the later and higher order of mammals of the Post-Tertiary and Quaternary eras the changes become more intricate and are more of a purely physiological character. The anatomy of the vertebrated mammals—whether of a paleotherium, hyena, deer, dog, horse, ape, or man—varies but little. The *fundamental osteology* is practically the same. External characters vary more widely, but are more superficial. All are propagated in precisely the same way—namely, by the production of an egg in the female ovary, the fecundation of the egg by sexual congress, and the transformation of the egg into the young animal in the female uterus, from which it is expelled into the world alive.

The most important changes that distinguish the higher animals from those of an earlier and lower order, besides those of their external anatomical configuration, are purely physiological in character, and act upon certain organs, the most important of which is the *Brain*. It is the more complete development of this organ which places one animal above another in the great scale of life.

The three forms of animal life just described—namely, the paleotherium, the anoplotherium, and the xiphodon—were the most important of any of the early Tertiary, or Eocene mammals. Europe seemed to have been their favorite habitat. There were many others besides, whose abundant fossil remains have been found in our western country, in Europe and Asia. Of these was the **Lophiodon,** a tapir-like animal not unlike the paleotherium, although less highly developed.

The **Titanothere** was another of the same order, a tapir-like animal also, whose bones have been found on the upper regions of the Missouri River.

The **Hyracothere** belonged to the same group, and had the tapir-like prehensile lip of the others.

These three animals—the lophiodon, the titanothere, and the hyracothere—were all doubtless derived from the paleotherium. They closely resembled each other, and had the same habits and modes of life. This affords another instance of lines of special animal forms which were derived from a common stock, running in parallel grooves of development, and showing, even up to the point of their extinction, but slight traces of divergence. These traces, however slight, were still sufficient to show some points of difference, and to require of naturalists a special notice and a separate name.

The **Chereopotamus**, whose bones have been found in our country, and in France, was a small pig-like animal resembling the modern peccary of Central America.

Whales also existed in the Tertiary period. A large species—*Zeuglodon cetoides*—was quite abundant in the southern seas of our continent. In Alabama, the vertebræ of these animals have been found measuring twelve inches in diameter, and were so numerous that they have been burned to rid the ground of them.

Some of these whales have been ascertained to measure from sixty to eighty feet in length. A mammal of such vast size, and of such prolific development, may almost excite our astonishment.

We have in this huge creature a marine mammal, whose habitat is wholly in the sea, whose habits are carnivorous, and who is a *vivipara*, bringing forth its warm-blooded young alive, and maintaining the respiration of atmospheric air by means of a true *air-breathing*, or *pulmonary* apparatus—namely, the lungs. What animal was the progenitor of the whale, and what was the process of evolution of such a gigantic vital organism? We have seen that the hylæosaurus of the Cretaceous period was an herbivorous reptile living upon the land, and propagating itself by means of eggs —a true ovipara; that afterwards by a slow and gradual change in its physiological functions, it became warm-blooded and transmitted to its successors certain qualities that caused an evolution of mammalian organs and mammalian functions, and these qualities and functions were sufficiently strong to develop in the course of ages an animal far above the level of the original saurian—namely, a true mammal—a vivipara.

A mammal originating in this way, from a land saurian, would retain certain saurian characters, as the powerful tail, and a rounded and somewhat elongated body capable of buoying itself upon the surface of the water. Such an animal, springing from a saurian, would find a marine life congenial to its tastes, and in its aquatic habits the strong tail served as an organ of propulsion. Under the potent influence of the law of *use* the tail grew larger and more powerful, and this growth, aided still further by the stimulus of increased nutrition, finally attained to an enormous development as a powerful propulsive or swimming organ. The tail of the whale lies flat on the water, with the fins or flukes spread horizontally, while fishes swim with the fins of their tails in a vertical position.

Why is this difference? The whale being an air-breathing animal, and not a fish, lives habitually upon the surface of the sea, and not in its depths, but when he desires to dive beneath the surface he gives his body a downward impulse by a blow of his tail upon the water, hence the flukes naturally tend to develop laterally instead of vertically, so they can lie flat upon the water.

By the continued operation of the law of use and disuse throughout long ages, the tail gradually developed into a larger and more powerful propulsive organ, until it became of vast size and great importance. By disuse the posterior limbs correspondingly atrophied, until in time they became rudimentary, being either represented by a small anal fin, or were wholly concealed in the integument.

The anterior limbs also changed in their anatomical structure. As the whale became permanently aquatic by finding a congenial habitat in the sea, the act of walking was abolished, and the form of the limb suffered a change. Its new uses as a swimming organ transformed it from a foot to a paddle, or pectoral fin ; but in this new configuration it still retains the same number and almost the same arrangement of its bones—namely, the humerus, the radius and ulna, and the small bones that form the carpus, and the five digits or phalanges. The paddle of the whale is a hand and not a foot.

We find, therefore, in the skeletion of the whale that certain changes have taken place in the process of its evolution, which distinguish it from the type of its original progenitor, the land saurian. The skull still retains saurian characters, but the teeth have undergone a change. There are none in the upper jaw. Those in the lower jaw are conical, and set at short distances apart, not close together. As his food consists almost wholly of small fish and crustaceans, his teeth are of but little use, and in the oldest whales they show but slight traces of wear.

The vertebral column is long, and terminates in a pointed extremity which supports the powerful lateral tail.

The pelvis, which existed in the saurian, and was so important a mammalian feature, also atrophies and becomes rudimentary. As it is no longer needed for purposes of sustaining the posterior limbs in the function of locomotion, it obeys the law of disuse and finally disappears.

The fossil remains of the Tertiary whales thus far discovered closely resemble the bones of the modern sperm whale. The teeth of the fossil whale are much like those of the present species.

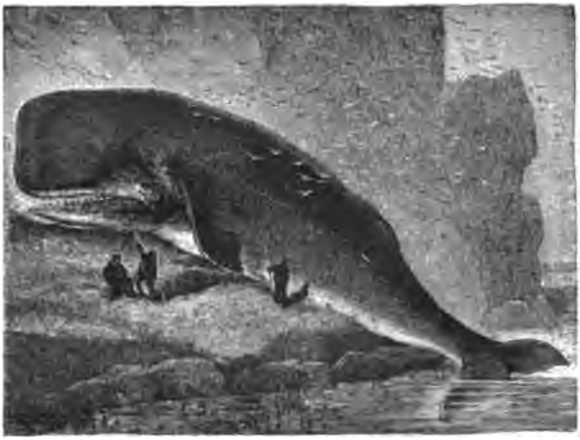


FIG. 59.—MODERN SPERM WHALE.

I have in my collection the teeth of a sperm whale I saw captured in the Indian Ocean, about two hundred miles southeast of the southerly point of the island of Madagascar. They are almost identical with some specimens of fossil teeth found in Alabama. In the upper Missouri and western regions of our own country have been found in considerable numbers the bones of several mammals. resembling those that have been continued down to modern times. Among them are the tapir, peccary, camel, and deer, as well as an animal, about the size of a fox, belonging to the horse tribe.

These horse-like animals that appeared thus early have been called **Eohippus**—from the fact that their fossil bones were found in a Lower Eocene horizon. They had four well developed toes, and one rudimentary toe on the fore-feet, and three toes on the hind-feet. In the Middle Eocene period another of these horse-like animals has been found—**Orohippus**—of a slightly higher grade of development than eohippus. He also had four toes in the fore-foot, but the rudimentary fifth toe had disappeared. His hind-foot had three toes. Later in the Eocene period, still another horse-like animal appeared—**Epihippus,**—whose dentition showed him to be slightly in advance of his two predecessors in point of development. An animal so important as these horse-like creatures were, leads us to inquire from what preceding animal was he descended. While this point is somewhat obscure, we are forced to the conclusion that he sprang either from the ancestor of the anoplotherium or from the early anoplotherium himself. The latter view seems entirely tenable. The early anoplotherium was a small animal, no larger than a fox, or the eohippus, and closely resembled him. He could easily diverge along lines extremely parallel, and in the ages of the Lower Eocene period produce the slightly horse-like eohippus. It was a long time afterwards before the true horse appeared.

The tapir and the peccary could have easily descended from the paleotherium, as we have already seen, by following a slightly divergent line of development.

The camel and the deer can undoubtedly claim the xiphodon as their ancestor.

A species of rhinoceros has been found also in our western country. As this vast region was once the home of the great megalosaurus, where he flourished so abundantly, he could undergo some anatomical changes in the course of the ages, induced by the higher needs imposed upon him by newer conditions, and so become transmuted slowly into a new animal form—the rhinoceros.

Several varieties of turtles *(Chelonia)* have been found both in our country and in Europe, in widely extended localities, during Cretaceous and Eocene time. They differed but little from the present living species.

The appearance of such an animal leads us to inquire by what process of evolution he came upon the earth. Who was his progenitor? In a previous figure we have a view of a large saurian, the teleosaurus, that lived in the Jurassic period. We see that this animal had a curious arrangement of the integument on his back and abdomen, which formed a hard and resistant *cuirass* or shield. It was marked off in rhomboidal or octagonal plates, and served as a strong defensive armor to the animal.

He was a vertebrate, and his fossil bones show that his osteological development was of an advanced order. He was also an ovipara, laying his eggs on the dry land, where external heat brought them to maturity. He was of amphibious habits, living both upon the land and in the water with the greatest freedom of movement. It needed but a shortening of the bones of the jaws—the pre-maxillary bones—and a shortening of the tail to change him to a turtle. Such a change in the anatomical structure of the teleosaurus could not occur unless a reason existed to induce it. No change in its physiological functions was needed. They remained the same in both species of animal. What brought about his change in anatomy? The teleosaurus sought his food in the sea, and to enable him to seize it, a long jaw and sharp teeth were necessary, as well as a powerful tail to propel him rapidly through the water.

As food became more abundant—and we know the Tertiary seas swarmed with a various multitude of life, —and as less effort was needed to procure it, the long jaw of this animal slowly atrophied through disuse, and at the same time the teeth became less developed. These qualities, naturally enough, were transmitted to successors, until a sufficient divergence from the original type occurred to cause individuals with shorter jaws and slower movements to seek each other and consort more together. At the same time, a more deliberate movement caused an atrophy of the tail through disuse. In this way the jaws, teeth, and tail of the teleosaurus suffered a change in structure, while the cuirass remained the same, and the new animal, with these modifications in his external configuration, was doubtless the turtle.

In modern turtles we see a considerable variety of form, habits, and special structure. These are, however, when closely examined, much less in degree than appears at first sight. All are constructed upon the same plan, and while some are marine and some terrestrial, they are all cold-blooded, vertebrated, oviparous reptiles.

The dorsal and ventral shell of turtles belongs to the tegumentary system, and is subject more or less to change in form. The tegumentary plates seen in the shells of most turtles is plainly a continuation through long ages, of the pachydermatous hide of the megalosaurus, modified by subsequent changes.

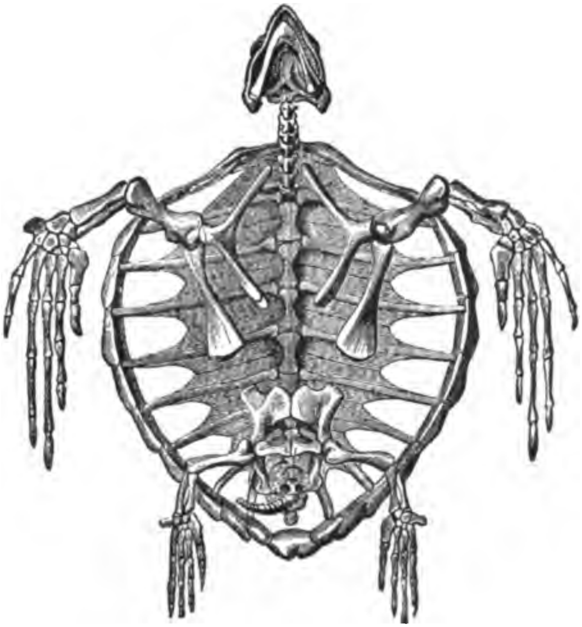


FIG. 60.—SKELETON OF TURTLE.

The skeleton of the order of turtles—*Chelonia*—is well shown in Fig. 60. It will be seen in this figure that the spinous processes have coalesced with the ribs, and these form an immovable bony framework to support the shell above, and to protect the internal organs beneath.

The bones of the skull, and of the anterior and posterior limbs are just the same in number, name, and uses as are those of all vertebrata.

The turtles of the Tertiary period, and many modern turtles cannot retire the head and limbs within the shell for protection, while others can do this with perfect ease.

The large land tortoises cannot do this, nor the large marine turtles. Fossil turtles are found in widely separated localities, showing they were unrestricted in their migrations. Land turtles are now found in many parts of the world, while the marine species are no less extensively distributed.

At the island of Ascension, a volcanic peak in the South Atlantic Ocean, I have watched the green edible turtle *(Chelonia midas)* as they came ashore on the beach at night to lay their eggs. They are found in great numbers in the sea near the island, and I have seen them fifty miles from the land.

I have a fine specimen of the tortoise-shell turtle I captured in the Magdalena River in Colombia, and another one I caught on the coast of Peru, near Callao.

In the Eocene period the **Dolphin** appeared, a true fish, the progenitor of the modern dolphins now so abundant in the warmer waters of the Atlantic and Pacific oceans.

In this period also appeared several forms of the great aquatic or marine carnivora—namely, the **Seal, Walrus, Sea-Lion,** and **Elephant-Seal.**

The fossil bones of these animals have been found in several localities on our Atlantic sea-coast, but in great profusion in that vast ancient fossil cemetery, in Montana, Idaho, and Oregon, where recent researches have brought to light so many forms of Tertiary animal life.

There can be no doubt that these four marine carnivora were evolved from a single progenitor, following the same line of development as the whale, and showing close parallelism in their structure, functions, and mode of life. All are carnivorous in their nature, living in the sea, but air-breathers, and more or less capable of moving on the land. They are warm-blooded mammals, bringing forth their young alive, and seek the shore at short intervals to nourish them.

The seals *(Phocidæ)* the walruses *(Trichechidæ)* the sea-lions *(Otariidæ)*, and the elephant seals *(Macrorhinidæ)*, have all sprung from a common stock, and from the same ancestors.

As the mammalian whale sprang from a land saurian, and in the course of ages became sufficiently modified to propagate himself as a new form of animal life, so these animals sprang from a saurian, and probably the same saurian, and in the course of ages, by following slightly varied lines of development, the closely allied forms as we now see them were evolved. In anatomical structure all the fossil bones are strikingly alike, both of the seal and walrus.

It seems there can be no valid doubt that these animals owe their origin to one of the earlier saurian forms of life, and from what we have already said in regard to the changes of anatomical structure and physiological function, they could easily descend in the course of time from such an animal as the hylæosaurus. In the slow modifications of this creature to produce a seal or a walrus, the intermediate forms would be less stable in structure than the complete animal, and consequently more liable to destruction.

If time and capital could be employed in an exhaustive research of the vast wealth of fossil remains found in Europe, and in our own country, only a small part of which has yet been subjected to systematic scientific inquiry, there is little doubt that many transition forms could be found.

The discovery of such transition forms is, however, not at all necessary to firmly establish the truths of evolution. *That* is a law as positive as any law in the universe.

When we compare the fossil bones of the seal of the Eocene period with those of living species, we see no practical differences between them. The ancient seals had a wide range of distribution as do those of our time, and while none of the Tertiary forms now exist, it seems probable that they lived in most of the localities where they are at present found. Modern seals prefer a cold climate and live by preference in the higher latitudes. They are found in vast numbers on the coasts of Alaska, and in the Straits of Magellan, near the Pacific entrance to the Straits, and in Smyth's Channel. I have seen them in such numbers playing in the water that our ship seemed sailing across a black plain. There must have been many millions of them. They were of the variety known as "hair seals," and being unaccustomed to the approach of man, and consequently fearless, we could almost touch them with our hands.

The head and teeth are decidedly carnivorous in character, while the spinal column, ribs, and bones of the anterior extremities are those of a mammal.

The termination of the spinal column, the imperfectly developed pelvis, and the longitudinal direction of the posterior limbs are peculiar, and bear a close analogy to the structure of the whale, and lead us to believe that the development of both in the Tertiary age was from a common saurian ancestor and proceeded simultaneously along lines of almost parallel evolution. The divergence is very slight when we actually compare the osteology of the two animals. The difference in size is only relative.

The sea-lion is more highly developed in his bony structure, and is consequently more active in his movements on land and in the water.

I regard the sea-lion as a more advanced development, structurally, than the seal. He undoubtedly sprang from the same saurian stock as the seal, and pursued the same line of evolution. In habits and mode of life he is essentially the same, and is found in nearly the same localities. I had an excellent opportunity for watching these animals on Dungeness Point, near the Atlantic entrance to the Straits of Magellan. I drew one of the ship's boats up on the sandy beach, and remained quiet in it. They took no notice of me, and crawled up on the beach from the water by thousands. They were playful, and delighted to chase each other from the shore to the water and back again, uttering all the while their harsh and discordant cries, in the performance of their awkward and ridiculous antics. Great numbers of penguin sat on the beach like sentinels, and while the sea-lions passed among them neither took the slightest notice of the other.

Both sea-lions and penguin would come close to my boat, look at me, and move away in the most indifferent manner. In examining the skeleton of the sea-lion, by comparison we notice a considerable advance in the development of the bony structure over the seals.

The walrus may be regarded in the same light as the seal and sea-lion in reference to his original evolution and development, his structure, habits, and mode of life. His essential points of difference refer to his dentition.

In the upper jaw are two long, powerful *tusks*, or canine teeth, sometimes attaining a length of two feet in a full-grown adult. These tusks were not so well developed in the early Tertiary walruses, as the fossil skulls of these creatures show. It is the *modern* species that is thus armed. The reason for this is evident. In the Tertiary seas, the early home of the walrus, the water was warm, the temperature equable, and food abundant and easily obtained. Under such favorable conditions the teeth remained of a carnivorous type, fitted for the simple uses of the animal. But in modern times the walrus is an arctic dweller, and in his home in icy seas he has to break his way through thick ice

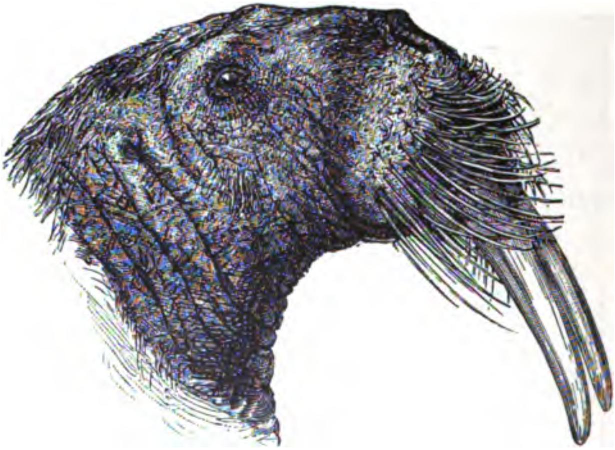


FIG. 61.—HEAD OF MODERN WALRUS.

to come to the surface to breathe, and he has an active enemy to avoid in the polar bear.

These two reasons would be sufficient to induce a special growth of his upper canine teeth. In his efforts to lift his body out of the water he aids himself by inserting his teeth, often with terrific force, into the ice, and thus drags himself up on it. When he has dragged his body in this way on the ice, a new danger confronts him, namely, the attacks of the formidable polar bear. The walrus must defend himself from this fierce enemy, and he does this by turning his head from side to side so as to present his teeth as weapons of defence.

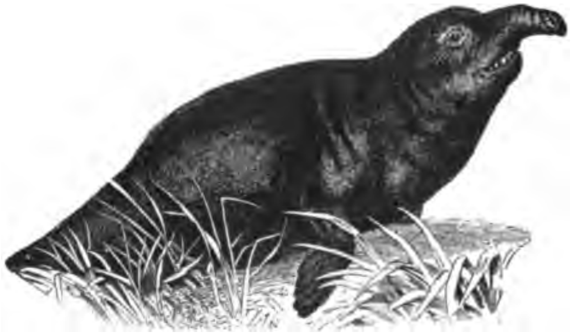


FIG. 62.—MODERN ELEPHANT-SEAL.

Under the law of use the canine teeth would be stimulated to greater development, until they reached the size we now find them.

In Fig. 61 we see the head of the modern walrus, and also his characteristic dentition.

The modern *elephant-seal* affords another example of the parallel development of animal life. Like the sea-lion, the seal, and the walrus, he owes his origin to a remote saurian ancestor, and, like them, set out on a path of parallel evolution, and differed at first but little from them. In the course of time, however, he found a new use for his mouth and lips in procuring food, and this new use induced an increased growth and greater development of the parts, until a sort of proboscis was formed, which the animal used as a prehensile organ. Fig. 62 shows this animal.

In his general anatomy he resembles the other animals of his class.

Some fossil vertebræ have been found, both here and in Europe, without any evidences of limbs, and from the peculiar characters of these bones, it is believed they were the first of the true snakes.

On what was in the Eocene age the Atlantic border of our continent, a large serpent has been found. This was **Titanophis,** an animal about thirty feet in length, and of aquatic habits. Several other species have also been found of considerably smaller size.

Fossil bones of several varieties of birds have been found in the Eocene beds of Europe and our own country. Some of them were long-limbed, and evidently belonged to a *wading* bird or stork—some were well defined, like hesperornis and ichthyornis, while others were less perfectly developed, showing they belonged to transition types of evolution.

The evolution of birds was undoubtedly from the dinosaurs. We have seen that these latter creatures were saurians that walked in a more or less upright position upon their posterior limbs. These reptiles, in the course of ages, diverged in their anatomical structure, and gave rise to animals that were very bird-like in their osseous anatomy—and these reptilian birds and bird-like reptiles have been found so well preserved that no reasonable doubt exists that the dinosaur was the progenitor of the birds. These Eocene birds were not, however, like our modern birds. Most of them had only a rudimentary wing, wholly incapable of buoying the body upon the air. The legs were long, which enabled them to wade with ease and safety in the lagoons and marshes of that period.

The act of aërial flight was doubtless developed long after their evolution and separation from their saurian ancestry. The effort of flapping these rudimentary wing-like extremities, continued during long periods of time, finally led to a more perfect development of the part through increased nutrition, and a consequent increased cell-growth, until a limb was developed that gradually partook of the characters of a true wing, capable of buoying his body in the air and of developing the power of true aërial flight, thus giving him the power of moving his body and propelling it from place to place in the air. The imperfect, bat-like wing of the pterodactyl of the Jurassic period was a web-like membrane stretched from the greatly elongated little finger to the sides of the body.

This anatomical structure has been without doubt transmitted to the modern *bats*, who fly with such an intermittent motion. But a deviation in development at length occurred, and the bones of the hand changed to give a firmer support to the expanded web.

This web was a thin expansion of the external integument or *skin*, and was delicate in structure. As a protection to it, little prolongations of itself were developed until the *hairs* thus formed became a protective covering, and greatly aided the act of flight.

These hairs, under the influence of long-continued activity, increased vascularity, and greater nutrition, in a dry air and sunlight, developed lateral ciliary processes, until finally the web-like membrane on the rudimentary wings of the Eocene birds became covered with these tegumentary growths or *feathers*. It was not until after a true feather was developed that a true wing could be formed capable of buoying the animal in the air in the act of flying.

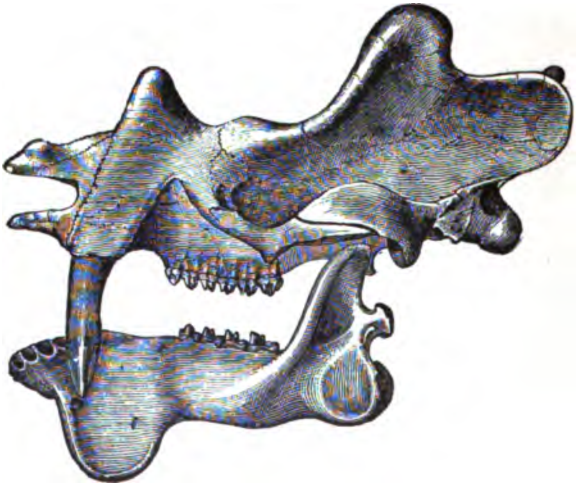


FIG. 68.—SKULL OF DINOCERAS.

The varieties of modern feathers, and their varied and often brilliant coloring, are superficial characters, and are mainly influenced by the habits of the animal, by environment, and by climatic changes.

Towards the middle of the Eocene period the great region lying between the Rocky Mountain range on the east, and the Wasatch range on the west became the home of a strange group of large mammals. In this special locality, in those remote ages, there were a number of great fresh-water lakes. The shores of these Eocene lakes furnished a congenial home to vast numbers of gigantic mammals who lived and flourished there in a remarkable degree. These animals have been called the **Dinocerata.** They were mammals of large size, with herbivorous habits, and a special dentition fitted for a vegetable diet. In the males there was in the upper jaw a long well-developed canine tooth or tusk, decurved, and having a sharp bayonet-like point. This terrible weapon made the beast a dangerous enemy. When the mouth was closed this tooth was protected by a wide bony process on the lower jaw. On the head were four roughened, uneven, bony horn-cores, showing the animal had ample means for defence. The entire bony skeleton was of great size and massive development.

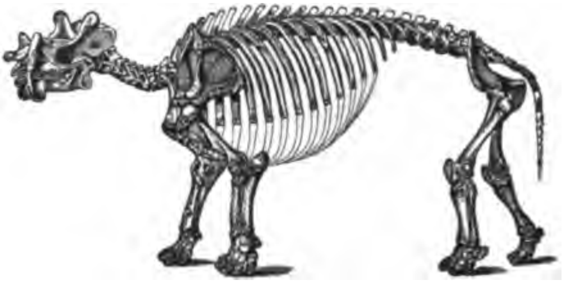


FIG 64.—DINOCERAS.

When we see the skeletons of these great elephant-like animals that lived near those Eocene lakes in our western country we ask at once what induced the development of such immense creatures, and from what previous animal form were they descended. The recent discovery of the dinocerata has made us acquainted with a new and strange species of animal unknown to us a few years ago. We know that this special region where they have been found was also the home, during Cretaceous and Eocene time, of other great animal forms. Here the paleotherium was evolved and lived and flourished, and it is very probable that this great animal diverged in the course of time and developed gradually into the greater and slightly more advanced dinoceras. All the conditions of life were favorable to such a change of form. The air was warm and equable, vegetation abundant and easy to obtain. Water in those ancient lakes was in profusion, and all of the conditions of life were easy. In such a scene of plenty it was easy for rapid development to take place through ample nutrition, which stimulates greater growth. The Eocene ages were sufficiently long for these changes to take place, and there can be no reasonable doubt that they did take place in this way. In a later age, when

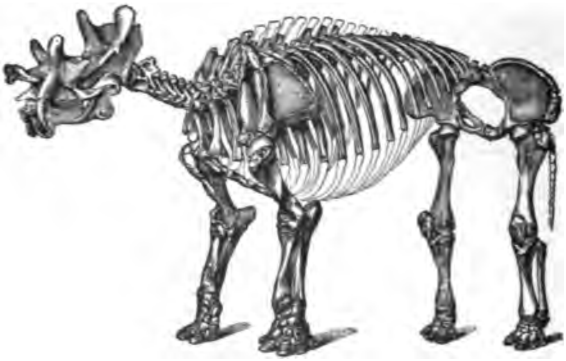


FIG. 65.—TINOCERAS.

this region was elevated to mountain heights, and the erosion of adjacent peaks, and the slowly deepening rivers drained those Eocene lakes and changed them to dry land, these great animals found themselves in a new and less favorable environment, and their extinction finally followed.

Their huge fossil remains have only been recently found in our western country by our own geologists. They were, therefore, solely a product of evolution of North America.

A remarkable development of minute marine molluscan life occurred in the Early and Middle Eocene ages—namely the **Nummulites.** These were little animals of an intricate structure that lived in a circular shell divided into many small chambers or partitions. From this special circumstance and from their resemblance to a coin they have received their name of nummulite, from the Latin word *nummus*—a coin.

They were thin and flat and measured from one third to one inch in diameter. When one side of the animal's shell is removed the little chambered cells are seen arranged in a regular circular coil. The minute delicate creature lived in these cells, and came in contact with the outer world by means of *cilia* or delicate thread-like filaments which passed out through numerous openings in the shell. This special anatomical structure has given him his scientific name of rhizopod, or animal with a *root-like foot.* When we examine the delicate shells of these animals attentively we are led to believe that they were formed by a string of cells placed in contact like a string of beads, and that they afterwards became coiled up in the shape of a coin, or like a coil of rope on a ship's deck. While in this position the cell-membrane of each cell secreted a quantity of lime and organized it into a row or series of little shells which afterward became connected by contact into a chambered shell. In this way the nummulite was formed.

Their propagation was doubtless from the formation of new cells by budding of the parent cell before the shell was secreted, and these aggregating and forming strings of cells gave rise to new individuals.

As they died after reaching maturity they sank to the bottom of the sea where they had lived, and their calcareous shells in the course of time hardened into stone, and it is now known as nummulitic limestone. It is of this stone, which is white, hard, and durable, that the pyramids of Egypt are built.

I have in my cabinet specimens of this stone, of a pure white color, in which the nummulites are distinctly seen. They were obtained in Upper Egypt.

The nummulites were exceedingly prolific and extensive in their distribution.

The beds of limestone composed entirely of the shells of these little animals are in some places more than three thousand feet in thickness, and play a far more conspicuous part than any other tertiary rocks in the solid framework of the earth's crust, either in Europe, in Asia, or in Africa.

These nummulitic beds occur in the London and Paris basins, and extend from thence to the Alps, where they reach a height of ten thousand feet above the sea. Then to the Carpathians and into Algeria, Morocco, and Egypt, and onward into Asia Minor, across Persia by Bagdad to the mouths of the river Indus. They form the great mountain ranges which separate Scinde from Persia, and the lofty passes leading to Caboul. They follow on still farther eastward into India and Bengal and the distant frontiers of China, and largely form the mountains of Afghanistan, the southern slopes of the Himalayas, and reach the stupendous elevation of more than sixteen thousand feet in Western Thibet.

When we reflect on the vast extent of these lofty mountain ranges, covering such immense areas in the Eastern Hemisphere, and remember that they are largely composed of the shells of these little animals, we can form some idea of the irresistible power of nature, and of how immensely prolific she is, especially in the lower forms of life, in producing such countless millions of little creatures, whose aggregated fossil remains form such vast areas of the earth's solid crust.

As these nummulites were marine animals living wholly in the sea, it follows that the great mountain systems, such as the Alps and Pyrenees, the Carpathians, and the lofty Himalaya range, which are so largely composed of their fossil shells, could not have uplifted their mighty barriers until late in the Tertiary period.

CHAPTER X.

THE CENOZOIC AGE:—THE TERTIARY PERIOD. THE AGE OF MAMMALS—CONTINUED.

The Miocene period—The Grand Cañon of the Colorado—Brontops robustus—Dinotherium—Mastodon—No missing link—Fossils from the John Day River—Fossils from the Siwalik Hills—Sivatherium—Development of the antler—The anoplotherium is the progenitor of the hyena, dog, and ape—Dog-like apes—Fruit-trees—Banksia—Mesopithecus—Lobsters—Crabs—Lignite—Amber—Diatoms—Mesohippus—Miohippus.

THE MIOCENE PERIOD.

THE Miocene period of Europe closely corresponds to the Middle Tertiary period of our own country. The changes that occurred in the area of dry land were inconsiderable. The continents remained practically the same. The temperature of the air was universally warm and equable, the trees and plants lived and flourished equally well everywhere—at the poles and under the equator.

The waters of the seas were still warm, and it is probable that they were also still *fresh*, or at the most only very slightly brackish, for although there were some rivers at this time, none of the *great* rivers existed, for the high mountain ranges that determine so largely the formation of river systems were not uplifted until long after the close of the Miocene period.

About this time the great area of land in our country now forming part of the States of Arizona, Nevada, and Lower California was uplifted above the sea and became dry land, a wide barren stretch of hard sedimentary rock resting upon other strata of rock that had been formed in the Cretaceous and Jurassic seas. This vast area of desolate rock attained an elevation in its most northerly part of about eight thousand feet above the sea, and thence sloped gradually in a southerly direction down to the Gulf of California.

The Rocky Mountains did not then exist.

As the rains fell upon this great stony waste, little channels were slowly cut in the rocks by the running waters. The direction of these streams was towards the south.

As time went on, the channels were cut deeper and deeper. Little side gullies were also formed by the waters from the falling rains, and these, pouring their added floods to those of the main channel, caused a more rapid erosion, which went steadily on for ages, until a deep, gloomy, and mighty cañon, the Grand Cañon of the Colorado River, was formed, with vertical walls in some places sinking to the stupendous depth of more than five thousand feet.

At the same time, the winds, with restless energy, adding their forces to the rains, wore away the surface rocks, first the Upper Tertiary layers, then the Cretaceous layers, and lastly the Jurassic layers, leaving the land in a series of great *terraces*, sloping towards the south, and cut deeply in many directions by the Grand Cañon and its numerous tributaries, some of which were almost as deep as the Grand Cañon itself. Here and there are seen masses of rock harder than the rest, which resist the action of wind and rain, and these have been left to stand alone, like great sentinels in the midst of a wide solitude, some having a dome shape, others rising like mighty columns or vast ruined temples. In Fig. 66 such a scene is well shown.

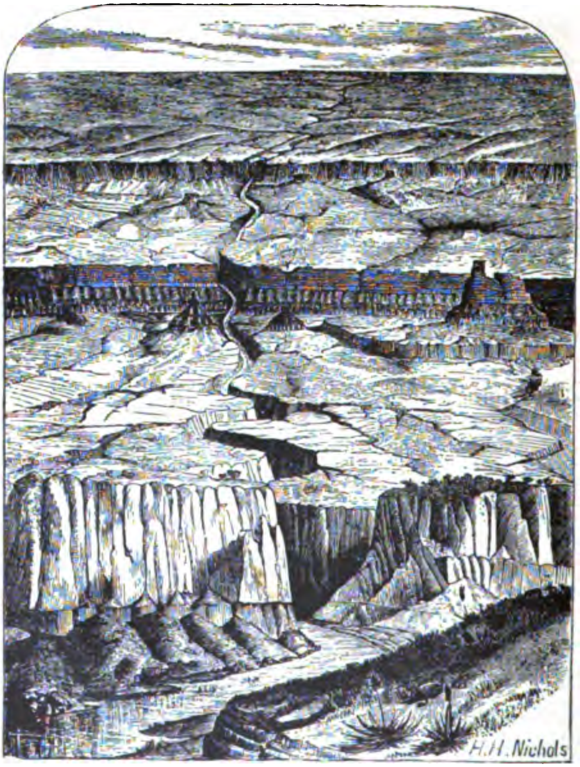


FIG. 66.—GRAND CAÑON OF THE COLORADO RIVER.

In the foreground we see the Grand Cañon where it has cut its way through the rocks. It winds away in a tortuous course and is lost in the distance.

The upheaval of these rocks occurred in the Tertiary period, toward the close of the Miocene epoch. The channelling of the rocks began some time after, probably during the Pliocene epoch, and has gone on, with some interruptions, until now. We can gain some idea of the immense lapses of time that are required to accomplish so great a work as the cutting through more than a mile of solid rock of the Grand Cañon of the Colorado. If there is enough time in a single geological subdivision to accomplish so vast a work in hard unyielding stone, there has indeed been ample time since life first dawned upon the earth to accomplish all the anatomical changes that have occurred in the plastic and easily influenced vital organisms that have successively appeared in the grand career of evolution.

During early Miocene time, the immense and fertile region that now lies along the eastern slope of the Rocky Mountains was a wide-stretching and nearly level pasturage. Great fresh-water lakes existed, the air was warm, and vegetation rich and abundant. In this favored region a new form of animal life was evolved, namely, the **Brontops Robustus.** He was of great size, nearly as large as the modern elephant, and, as he had herbivorous habits, he found a congenial habitat, well adapted for a great anatomical development, in that region of luxuriant vegetation. The brontops lived in large herds in that highly favored locality, and, as he found the conditions of life easy, he developed rapidly. The fossil bones of this animal have been found in great numbers in recent years in the Miocene deposits lying along the eastern borders of the Rocky Mountain highlands. In the Yale Museum, at New Haven, Conn., are nearly two hundred skeletons of this huge animal. In Fig. 67 we see the restored skeleton of one of these creatures.

If we compare him with dinoceras and tinoceras, we shall see that he is a continuation of development of those two great Eocene mammals, and it is extremely probable that he is descended from them, and is a more advanced type of the same animal, having become more highly developed in a later and more favorable age, amid surroundings that contributed to his greater anatomical growth.

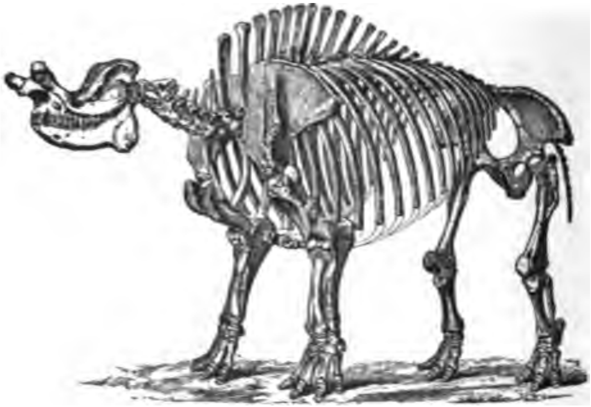


FIG. 67.—BRONTOPS ROBUSTUS. (MARSH.)

The brontops has thus far only been found in our own western country. Here he seems to have been evolved, and here he lived for ages and died. In that age, when a tropical verdure overspread the whole earth, when the arctic regions were as favorable to the support of animal life as the regions near the equator, animals migrated with ease from America to Europe across the Arctic Archipelago. The *brontotheridæ* could have thus easily migrated until they reached the great European pastures, and there in the course of ages slowly changed into other and modified shapes. Such a modified shape is the **Dinotherium,** whose fossil bones have been found in several localities in Europe. This animal closely resembled brontops in size, form, and in his bony anatomy. He was of nearly the same size, and had the same habits, being a vegetable feeder. But, unlike brontops, the dinotherium had sharp recurved tusks or canines in the lower jaw. The development of these tusks was due to the habits of the animal in digging in the ground for succulent roots, upon which he delighted to feed, in addition to his ordinary herbivorous diet.

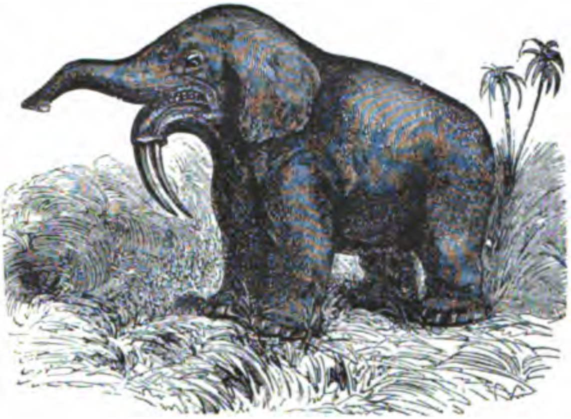


FIG. 68.—DINOTHERIUM.

In Fig. 68 we see a restored outline of the dinotherium, with his short proboscis or trunk.

The dinotherium was without doubt a modified brontops, and his modifications in anatomical structure were due to a changed mode of life. His osteology differs but little either in the size, shape, and functions of the bones.

He is a modified brontops, and, in a new region and amid slightly different surroundings, he has followed a line of evolution and development deviating but little from that animal. He is not greatly unlike his progenitor, while his habits and physiological functions are the same.

His general modes of life, also, are the same. His main differences are his size, and his recurved tusks in his lower maxillary bone, or jaw. The development of these tusks could easily occur in the course of time by a habit of using the lower canine teeth in digging in the ground for rhizomatous food.

The dinotherium belongs to the same order of animals as the pig, peccary, tapir, and elephant.

He was an intermediate form, living just before the true elephants appeared, and having attained a prodigious bodily development, continued on through the Tertiary period, and finally became extinct.

The **Mastodon,** another of those great elephant-like animals, appeared in the Miocene period. He is by far the most important and interesting of this special group of huge pachyderms. He has received his name from the peculiar teat-like projections on the surface of his molar teeth, which are arranged in pairs. From this anatomical peculiarity of his dentition, Cuvier called him the mastodon—the teat-like toothed animal. His favorite habitat seems to have been the southerly slopes of the Laurentian Hills, in our own country, as the finest fossil bones have been found on the banks of the Hudson River, near Newburgh, and also in Ohio, Louisiana, and on the upper Missouri, and in Oregon. Later in his career he passed to the north also, and went down through Siberia and Russia, as far south as France, where his bones have also been found in a well-preserved fossil state. In this new scene, to which he had migrated from his original home in North America, he found an agreeable habitat and the conditions of life easy. This extensive region, now known as Europe, stretched away in fertile beauty, and afforded an agreeable abode for the mastodon. He was even of a more advanced order of development than the dinotherium. He had four long, straight tusks, instead of two. The upper pair proceeded from the anterior part of the upper jaw—the pre-maxilla—and were an extraordinary growth of the superior canine teeth.

The lower pair of tusks were also an extraordinary growth of the inferior canine teeth. They were nearly straight, and not recurved downward, as in the dinotherium.

The trunk, or proboscis, of the mastodon reached to the ground, while in the dinotherium it was short, and did not quite reach the earth. Why is this difference in the length of trunk of the two animals so nearly alike in bodily structure? The reason is plain. Both were herbivorous animals, with habits and modes of life nearly alike. But the osteology of the mastodon differed slightly from that of his cotemporary. He was a little thicker and heavier in the form of his skeleton. His legs were longer and heavier. His *ribs* encircled his abdomen as well as his thorax. His cervical vertebræ (seven in number) were shorter and more flattened antero-posteriorly, and his dorsal spinous processes were very long and powerful, to give attachment to the strong *nuchal* ligament necessary to support his ponderous head.

A glance at Fig. 69 will show these important points in his osteology, and they determine to a great degree the development of the external superficial parts. Such a huge animal denotes an *immobility* of body, and this must be compensated for by a growth of a muscular trunk or proboscis, long enough to reach the ground and bring food and water to the mouth.

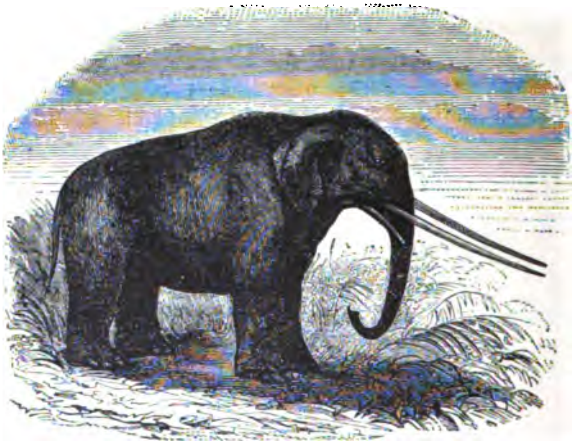


FIG. 69.—MASTODON.

The development of the long upper tusks was to enable the animal to dig in the ground for roots which formed a part of his food, and for such defence as he needed. The lower tusks were not so important to his wants, and they are consequently more rudimentary.

If the mastodon is a higher organization than the dinotherium, and there can be no doubt of this, the strong re-curved lower tusk of the latter animal being no longer needed, becomes, in the course of time, in the former animal, an atrophied and much less important organ.

The operation of the law of *use* and *disuse* is nowhere more clearly seen than in the development of this huge creature: of *use*, in the growth of the trunk and superior tusks to meet a *special* need; of *disuse*, in the retrogression and atrophy of the inferior tusks when they no longer subserve a useful end.

In Fig. 69 we have a restored outline of this huge animal, now extinct, who lived and flourished in the Middle Tertiary or Miocene period, when our earth was a continuous garden, blossoming in a perpetual summer. Fanned by warm and equable breezes, watered by copious and agreeable showers, with a luxuriant vegetation growing everywhere, and immunity from wild and dangerous beasts, it is no wonder that the evolution of animal life proceeded rapidly, and produced such gigantic vital organisms, under conditions so extremely favorable.

Abundant food, external environment, and great lapses of time, exert a powerful influence in modifying the anatomical structure of animal forms. Deviations from a former type, however slight at first, become great in the course of time, and produce an organism differing widely from the original type. These differences are, however, much less than would appear at first sight, when we examine them closely. As we follow on step by step the order of evolution from the first vertebrate—the fish—through all the intermediate steps in the ascending scale, until we arrive at the highest of all—man—we shall see a gradual advance in form, structure, and adaptability of parts to uses, and in intelligence, but in all this steady progress of development there is a continual modification of only one simple plan.

We need not look for lost intermediate forms—for *missing links*—to connect one form of life with another. There are no links wanting in the long and orderly chain of the evolution and development of life. If we study the material before us, and avail ourselves of the many aids of modern science, we shall find the whole chain of life on the earth complete, with nothing wanting, from the little protoplasmic cell of the Silurian age to the man of the twentieth century.

In two widely separated localities on the earth's surface—namely, the region on the John Day River in Oregon, in our country, and on the plains of India near the Siwalik foothills, on the southern slope of the Himalaya Mountains—have been recently found a large number of fossil bones of animals, believed to be of the Miocene, or Middle Tertiary, age.

Those in Oregon were discovered in June, 1889, by a scientific expedition sent out by Princeton College, New Jersey.

Those in India were discovered a few years since by English and French scientists.

In both regions the bones have been shown to belong to the same kind of animals, all now extinct, but some of which have doubtless been the progenitors of a few modern species. Among these fossils were the bones of the mastodon, rhinoceros, a three-toed horse, the anoplotherium, the dinotherium, a pig-like animal (probably a peccary), a tapir, a stag, the sivatherium, and a species of deer (probably the xiphodon), as well as a hyena, dog, and a species of dog-like ape. In both localities are wide, grassy plains, and were so in the Miocene period, long ages before the Rocky or Himalaya Mountains were uplifted into their present extensive ranges. We may infer that these ancient animals had a wide range of geographical distribution in the favorable conditions of those times, and naturally congregated in places where food and water were most abundant, and where the landscape was most agreeable to them. That they have not been found in other localities means either that they have not yet been searched for by geological methods, for the sciences of both geology and zoölogy are still in their infancy—or perhaps their bones have been lost in the great disturbances that followed the upheaval of mountain ranges in a subsequent age. Those that have been found belonged to the animals of the Miocene and perhaps of the Eocene periods.

None of them belonged to any modern animal type such as now exist on the earth.

The bones of the **Sivatherium**, so called in honor of *Siva*, an Indian deity who is worshipped in that part of India, have been found in America, on the plains of Northern India, and in a few spots in Europe.

It was a large herbivorous mammal, having a stag-like form.

The head and a few bones only have thus far been found, but these were so distinctive of a special animal form that naturalists have restored his external configuration with a singular degree of fidelity.

In Fig. 70 we have an outline of the animal restored.

Certain points in the anatomical structure which strongly resemble the xiphodon lead us to believe he is descended from that animal.

If we compare him with the xiphodon we shall see that he is of the same family, and has the same general structure, and has deviated from him but slightly, and along a line of *almost* parallel development.

The *antlers* of the sivatherium distinguish him from the xiphodon, as well as his more compactly developed body.

It will be noticed that he has *two* pairs of antlers. The brow antlers are small at the base, bend sharply forward, and terminate in branching points or tines.

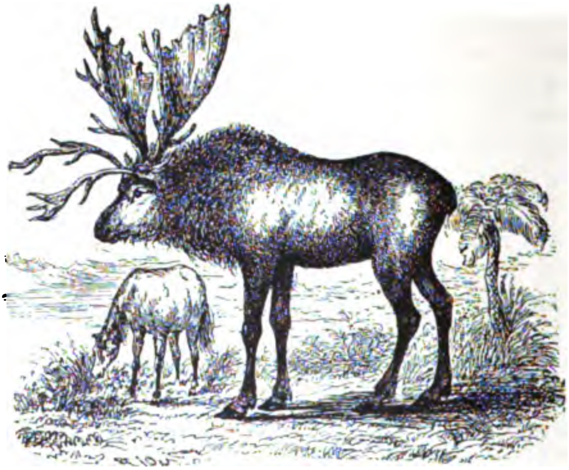


FIG. 70.—SIVATHERIUM.

The head antlers are larger at the base and expand suddenly in a vertical position into a broad palmate form, surmounted by several short serrations or points.

The development of the antlers is the same in the whole order of the Cervidæ or deer species, no matter how varied the shape or complicated the form. The sivatherium was the first antlered animal that has thus far been discovered in the Tertiary deposits, and the process of development of an antler, begun originally in him, was undoubtedly the same that prevails to-day.

What induced the evolution of the antler? It is well known that the males of the whole order of Cervidæ or deer are extremely eager, jealous, and warlike in their disposition, especially at the rutting season, tolerating the presence of a rival with great impatience. Indeed, this disposition is so fierce that it makes them dangerous at this season, not only to other animals, but to their own kind.

Their method of warfare is to fight with the head.

It is further known that the strongest and most generously nourished animals have the largest and heaviest antlers.

As the sivatherium used his head in warfare against his enemies the integument of the part naturally tended to hypertrophy under the stimulus of increased vascularity, greater nutrition, and the law of *use*. In time a knob or protuberance of skin formed by a bulging up of a pointed fold of integument, and the inner surface or cavity of this fold gradually assumed the power of secreting osseous or *bony* material, in the same way as the *periosteum* secretes bony material. The membrane lining the inner surface of this fold of skin acted like a secreting periosteal membrane, just as we now see in the case of the periosteal membranes of bones.

By this process of the secretion of bony material from the lining membrane of the fold of skin the first or rudimentary antler was formed.

This fold of skin in the modern deer species is called the *velvet*. It is smooth, delicate, and extremely vascular, and it secretes from its internal surface the bony material that goes to form the antler.

This process is now well known, and occurs constantly before our observation. There is a strong scientific reason for believing that the process was precisely the same in the case of the primitive antler of the sivatherium of the Miocene period. The *antler* differs from a *horn*. It is a true bone, secreted, as we have seen, by a periosteal membrane situated in the interior of the *velvet*, while a horn is a part of the tegumentary system and grows from it. The primitive antler was no doubt of simple structure, consisting in the first instance of a single projecting point or tine. It gradually became more elaborate by the growth of lateral expansions into branching points until, during the long ages of the Miocene period, it became an exceedingly complex and highly developed appendage.

The growth of a heavy antler induced a change in the anatomical structure of the animal's neck. As the head weighted by these appendages grew heavier it required a stronger support, and this induced a greater growth of the nuchal ligament, and this again induced an increased growth of the spinous processes of the dorsal vertebræ to give attachment to the ligament.

Hence we have a thick and powerful neck in the sivatherium as a consequence of the development of a large and heavy antler.

The bones of a species of hyena, dog, and a dog-like ape that have been found near the John Day River in Oregon, on the upper Missouri, and in that great ancient fossil cemetery in Northern India, have all undoubtedly sprung from a single ancestor, the anoplotherium.

If we refer to this animal we shall see that it required but a slight modification of anatomical structure to produce the **Canidæ** or dog species. The hyenas belong to the same order of animals. The evolution of these

—the dogs and hyenas—was the result of a simple deviation along two lines of very similar development, and very close parallelism, from the same ancestor. The structure, habits, and modes of life are the same in both animals. Both are carnivorous, with strong *scavenger* habits, delighting to feed on dead and decaying organic matter.

Both have transmitted these characters to their modern successors. The modern hyena still remains in a feral state, a carnivorous, nocturnal scavenger, incapable of taming or domestication. The development of teeth and claws results from his flesh-feeding habits, and from his instincts to scratch the ground to hide his food or to cover his ordure. His claw is blunt and non-retractile, and in this respect differs from the sharp and retractile claw of the order **Felidæ**—or cats.

The modern dog retains his carnivorous, scavenger habits, but in the complete process of domestication he has undergone, he has masked his scavenger tastes, and will eat sound food.

He still retains, however, a powerful tendency to revert to the feral state, becoming wild and ferocious when abandoned by man. His feral instincts and scavenger habits manifest themselves frequently, even when long cultivated as a household pet. His wildness is shown by his habit of turning round and round on his bed before lying down.

His scavenger instincts manifest themselves by his delight to roll his body over carrion and manipulate it before eagerly devouring it.

His teeth and claws, like those of the hyena, are developed in the same way. The sharp canine teeth in the upper and lower jaws act as *prehensors* to seize and hold his prey.

As he only uses his claws to scratch the ground, they are blunt, and the retractor muscles, not being needed to protrude them, are rudimentary.

Both the dog and hyena of the Miocene age are less completely developed in their osteology than the modern species. The scapulæ, dorsal spinous processes, and the pre-maxillary bones of the ancient hyena show a more incomplete development than do those of the present species.

These two animals of the ancient world were scavengers—carrion-feeders on the land, as the sharks were in the sea. Their special development of body was due largely to this fact.

The hyena has transmitted his special traits to his successors, unchanged, except so far as they are more sharply defined through the influence of a higher anatomical development.

The dog—in the later age—has been subjected to the modifying influences of domestication at the hand of man. The changes of form he has undergone by the process of cultivated breeding are very great, and serve as a vivid illustration of the extreme readiness of plastic vital organisms to undergo great and important changes of anatomy and physiological function, through external influences.

When these influences are exerted through long periods of time, the *ultimate* results are very great, even although the steps that lead to them seem very slow.

We come now to the evolution of an important animal, who first appeared in the early Miocene age at the same time as the dogs and hyenas. This was the **dog-like ape.**

His fossil bones have been found in considerable numbers in Oregon, and along the eastern slope of the

Rocky Mountains. There seems to be ample evidence that this animal originated in North America, and migrated in a later age to Europe and Asia, across the Arctic Archipelago, and along the Isthmus of Panama.

When we study the fossil bones of these dog-like-apes, that have been found in our own country, in Europe, and the Siwalik Hills of India, we find them all strikingly alike, and this fact leads us to the conclusion that they all belonged to the same species of ape-like animal. After his original evolution in our western country, he migrated to Europe, and thence to Asia and Africa. In this latter country he underwent important anatomical changes and developed into the higher man-like ape. He finally became extinct in North America, the home of his birth. When we compare the bones of this early Miocene ape with the bones of the hyenas and dogs of the same period, we find strong anatomical resemblances, and this leads us to the scientific conclusion that they all must have sprung from the same ancestor—that they all originally came from a common stock.

What animal was the progenitor of the dog-like ape? Undoubtedly the anoplotherium.

It is evident that he could not have descended from the tapir-like paleotherium, nor from the deer-like xiphodon, and as there were no other known animals at that time from which he could possibly have descended, it seems clear that the anoplotherium was his ancestor. His descent from this animal was another example of the slow divergence of animal forms from a single progenitor. He diverged more rapidly than either the dogs or hyenas, and the reason for this is not difficult to discover. It is this: It will be remembered that in the Miocene period the forest trees were large, and of nearly the same varieties as we now see. Among them were several kinds of fruit-trees, notably the *Banksia*, with its large and succulent fruit. As we know the apes are now eminently *arboreal* animals, there must have been a time when they first began to live in trees. The act of climbing in trees must have been acquired very gradually, and in order to be able to do it, the act of grasping with the anterior limb must be slowly developed.

This *adaptive growth* of a limb capable of grasping, to enable the animal to climb and to seize an object, marked a great advance over other animals, and a much wider divergence from them in point of special development.

If the dogs, hyenas, and dog-like apes set out on a path of development from the anoplotherium, and pursued it for a time in close parallelism, a point was ultimately reached when the special modes of life of the apes caused a wider and more rapid divergence. The mode of life which caused this special divergence was the habit which he acquired of feeding on such fruits as then existed, and in order to obtain them he must seek them in the trees where they grew. Now this makes it necessary that he must climb in the trees, and, when once there, he must seize the fruit with his anterior limb.

Here adaptive growth to meet a special need comes into activity, and as a result the osteology of the animal undergoes a change. From a terrestrial animal he becomes purely arboreal in his habits, and this new mode of life leads him to perform new acts, such as climbing, leaping from branch to branch, or swinging from tree to tree, in order to obtain the fruits that grow high up out of ordinary reach.

These acts, continually performed for long periods of time, finally resulted in an increased growth of the bones of the anterior limb or *arm*—namely, the humerus, radius, and ulna, but especially of the metacarpals and the phalanges.

Increased growth of a part or an organ depends upon increased nutrition, and this again is stimulated by increased muscular activity.

The bones grow by an increase in their cell-elements—for bones are formed of cells,—and the better the nutrition of the animal, the greater will be his secretion of bony cell-material.

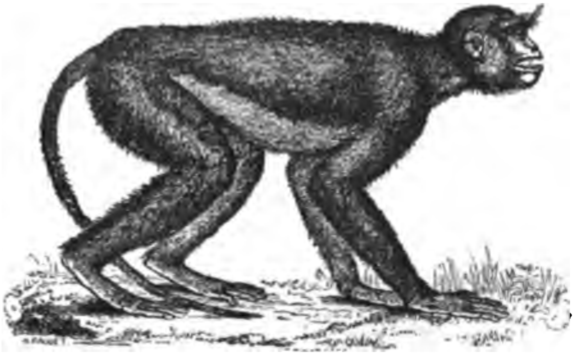


FIG. 71.—MESOPITHECUS, OR APE OF THE MIOCENE PERIOD.

A reference to Fig. 71 will show this ape in his restored contour.

This species of ape has been called the **Mesopithecus.** He was, however, much less highly developed than this restored figure shows. The fossil bones of the apes that have been found in the Miocene deposits show that this animal was of a much lower degree of development than any of our modern dog-like apes.

The Miocene period was remarkable for the development of a large number of important terrestrial mammals, as we have seen.

During this era, a number of crustaceans also made their appearance. Among them were lobsters and crabs approaching the modern species. These crustaceans were a continuation of the species that began with the trilobites of the Silurian seas.

A number of new mollusks came upon the scene at this time, mostly univalve gasteropods, some with a shell terminating in a long spiral fluted point, or in a point armed with complex curved or straight spines.

These were a continuation of the earlier univalve mollusks, whose evolution and mode of development we have already described.

In our country and in Europe we find in the Miocene and also in the Eocene periods a vegetable substance which geologists have called lignite. It occurs in beds varying in thickness from two inches to several feet, and is no doubt the result of a chemical change of the forest woods of a previous age. In some localities it is used as fuel. There can be no doubt of its vegetable origin, for we have abundant evidence of this fact in the markings and imprints of leaves and stems so often found in it.

A peculiar product of lignite is yellow *amber*. This is a sort of resinous substance which has undergone a change in the lignite beds. The original resin from the trees has been probably altered by heat, until it has formed clear melted masses, of a bright yellow color, and semi-opaque or almost translucent. These masses have cooled, and the amber is a resinous, brittle product, susceptible of being carved and polished. For more than two centuries this substance has been highly prized, and sought for principally on the shores of the Baltic Sea, where it is often washed ashore by the waves.

I gathered several specimens of amber on the German coast of the Baltic, about fifty miles northeast of Swinemunde. Here it was washed ashore in small masses,

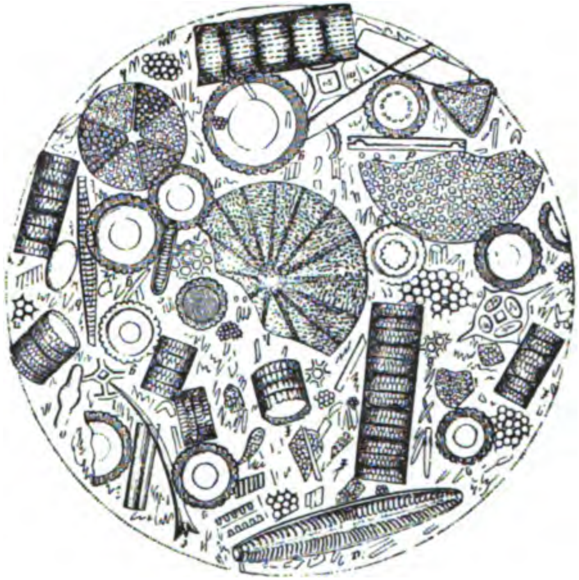


FIG. 72.—DIATOMS OF THE MIOCENE PERIOD.

and I found it on the sandy beach with pieces of decayed lignite and modern sea-weeds.

Among the smaller organisms of the Miocene period are the microscopical infusorial creatures known as **Diatoms.** These appear to the naked eye as minute grains of sand, but when placed under the microscope they are found to be animal organisms, complex in structure, and beautiful in appearance.

We are struck at once with the great variety and complexity of these little creatures. We gain a good idea of them in Fig. 72.

We see here that they are of various forms and exceedingly complicated in figure. A careful examination of them leads us to the conclusion that they belonged to the molluscan world, that they were in fact mollusks, perfect in development and in function. Some were undoubtedly cephalopods, some gasteropods, and some rhizopods.

The evolution of these tiny but perfect organisms was from cells, like their greater brethren of the same species.

They, too, in their almost invisible sphere of life absorbed lime from the water and elaborated it into shells, by the same process as the ammonites, belemnites, and other great mollusks elaborated *their* shells.

Like all the minute forms of life, they were exceedingly prolific and of wide distribution. I have gathered some beautiful specimens of diatoms in the West India islands of Barbadoes and St. Thomas; in California, Missouri, Maryland, and Virginia in our own country; in France, near Cherbourg, and on the Mediterranean coast of Africa. From this it will be seen how widely distributed over the temperate zone these animals were and where they are now found.

When more extended researches are made, it is probable that they will be found even more widely distributed than at present known.

Near the base of the Miocene deposits of North America, there have been found the fossil bones of a horse-like animal, about as large as a sheep. It had three toes on the anterior feet, and a rudimentary or splint bone besides, while the posterior feet had but three toes, the others remaining undeveloped. This was the **Mesohippus**, and was one of the series of horse-like animals which appeared in the Eocene age. At a somewhat higher geological horizon in the Miocene age, still another of these horse-like creatures was evolved. This was the **Miohippus**, or Anchitherium. He differed from mesohippus in having the outer splint bone reduced to the merest rudiment, showing that the evolution of these animals was steadily tending towards a one-toed animal.

All these fossil polydactyl horses have been found only in our own western country. As they were imperfectly developed in the Miocene age, they did not migrate beyond the limits of the field of their original appearance.

CHAPTER XI.

THE CENOZOIC AGE:—THE TERTIARY PERIOD. THE AGE OF MAMMALS—CONTINUED.

The Pliocene period—Elevation of mountain ranges—Rocky Mountains — Andes — Himalayas — Heights of mountain peaks—Volcanoes—Valley of Chili—Erosion of mountain summits—Formation of rivers—Perpetual-snow line—Melting snows—Saltness of the ocean—Fossil bones in our western country—Fossil bones in the Siwalik Hills—Camels—Musk-deer—Elephant—Rhinoceros — Amynodon —Hyracodon—Aceratherium— Hippopotamus — Protohippus — Pliohippus— Zebra—Quagga—Ass—Tarpan—Eagles —Vultures—Plants—Outlines of continents—North polar regions—Evidences that North and South America were once connected by a bridge of land—Evidences that the Malay peninsula was once connected with Australia—Oreodon—Eporeodon.

THE Pliocene period of Europe corresponds to the late Tertiary period of our country, and is the last of the three European subdivisions of the Tertiary epoch.

It is remarkable for the severe disturbances of the earth's crust, of immense extent, that occurred during this time, and which resulted in the final elevation of some of the great mountain ranges of the earth. The Rocky Mountain chain of North America, the Andes or Cordilleras of South America, and the Himalaya range of Asia, were uplifted to their vast heights at this time, as were also the Alps and Carpathians. The Rocky Mountain range begins far north in British Columbia, and extends in a general southerly direction through the western part of the United States to Mexico, and thence onward to the Isthmus of Darien. Here the range sinks to a height of only a few hundred feet, and continues this low altitude until it traverses the isthmus and reaches the continent in Colombia. At this point the range suddenly rises to a stupendous height, and maintains this lofty elevation almost uninterruptedly along the western border of the continent, until it reaches Patagonia. Here it gradually diminishes in height, and at its termination in Terra del Fuego, it is a series of irregular and broken peaks. The South American part of this immense mountain range forms the Andes or Cordilleras. The Himalaya Mountains form a magnificent frontier in Northern India, and separate its low and grassy plains from the elevated table-lands of Thibet. They curve slightly southward, and follow a course of more than a thousand miles from east to west. This range contains the loftiest summits on the earth, and a large number of its peaks are covered with perpetual snow.

The name Himalaya means the "abode of snow."

The present elevation of the more lofty peaks of these mountains is as follows :

Asia.		
Mt. Everest,	Himalayas,	29,000 feet.
Kuntchinjunga,	"	28,156 "
Dhawalaghiri,	"	26,826 "
North America.		
Mt. St. Elias,	Rocky Mountains,	19,283 "
Uncompahgre Peak,	" "	14,540 "
Pike's Peak,	" "	14,147 "
Mexican Plateau.		
Orizaba,	Peaks of Mexico,	17,897 "
Popocatepetl,	" "	17,784 "

South America.

Aconcagua,	Andes Range,	23,421 feet.
Chimborazo,	" "	21,424 "
Antisana,	" "	19,137 "
Cotopaxi,	" "	18,870 "

It will be seen that the two loftiest mountain summits in Asia and America are Mt. Everest in India, and Aconcagua in South America.

Their altitude rises into the regions of perpetual cold.

Aconcagua lies in the republic of Chili, almost immediately under the latitude of 32° 38′ 30″ S., longitude 70 W. from Greenwich.

Mt. Everest lies in the middle of the Himalaya range, in the 27th parallel of north latitude, and the 86th meridian of longitude east from Greenwich.

They lie, therefore, about 11,000 miles apart, in a southwest and northeast direction from each other. Great as they may appear to us, they are very small when compared with the size of the earth.

These two great peaks bear to the earth the same proportion that a marrow-fat pea would to a 15-inch globe, or a diameter as 1 to 60. They bear a still less proportion in their *mass* to that of the earth, being as $\frac{2}{10}$ is to 675½. The height of these peaks above sea-level is nearly five and one half miles, and the proportion of this height to the diameter of the earth is as 11 to 16,000.

Both of these mountain summits rise into the regions of perpetual snow, and are therefore permanently snow-clad.

The perpetual-snow line in the latitude of Aconcagua lies at an altitude of 16,000 feet, and descends gradually until it reaches the sea-level as we approach the south pole. At this calculation, 7,421 feet, or a little less than two miles, of the upper peak of Aconcagua lie in the regions of eternal snow.

The perpetual-snow line in the latitude of Mt. Everest is about 16,000 feet, and as the Himalaya range lies in an easterly and westerly direction, the altitude of the snow line of this range does not vary. About 13,000 feet of the upper peak of Mt. Everest, or about two and one half miles, are covered with never-melting snow. This great mountain barrier exerts a sensible influence on the climate of Asia, and largely determined in a later age the growth and distribution of plants and animals.

The Rocky Mountain system of North America is not a single straight chain, but a series of mountain ranges, having a width of about four hundred miles from east to west, and each range having a separate local name.

The valleys and intervening lands form parks and *mesas* of extraordinary fertility, and reach an elevation of from 7,000 to 10,000 feet above sea-level.

These mountains abound in vast mineral wealth, are abundantly watered, and wooded with pine, fir, and spruce, to the verge of the timber line. Above this line are found—first, a few stunted shrubs, then some low, hardy mosses, followed by naked rock, which pass finally into the regions of severe cold and perpetual snow.

The city of Leadville, in Colorado, is located at an altitude of 10,000 feet. The Denver and Rio Grande Railway crosses the great Continental Divide at Marshall Pass, over Mt. Ouray, at an elevation of about 12,000 feet, or close to the edge of the timber line. The perpetual-snow line here is 12,500 feet.

I ascended Mt. Ouray recently, and found, during the middle of August, a vast body of snow, packed hard into a mass of coarsely granular ice. The sun's rays fell full upon it, but did not melt it even at noonday.

The valleys and *mesas* of this region are extremely fertile when irrigated. The soil is *adobe*, which is disintegrated pulverulent rock, with its contained alkaline salts. Wheat, corn, and fruits grow abundantly; and the streams from the melting snows furnish an abundant supply of pure water, fit for potation and irrigation.

So fertile is this region, and of such immense extent, that if the Rocky Mountain region could be inclosed by a line beginning on the eastern border at the southeast corner of New Mexico, running thence slightly northwest, intersecting the city of Denver, and continuing in the same direction, through Wyoming and Montana, to the line of British Columbia, and by another line on the western border of the mountains exactly parallel to it, and intersecting the Salt Lake City, it would comprise a territory of sufficient extent to support the entire population of the earth.

The agricultural and mineral resources of this vast area would profitably employ and comfortably support all the people that now live upon the earth.

The Andes Mountains form a high wall along the entire western border of South America.

From Ecuador to Patagonia they recede from the coast from fifty to one hundred and thirty miles.

I ascended the Andes over the Oroya Pass, in Peru, at an altitude of about 16,000 feet. The snow line at that point was about 14,000 feet. The rocks at this elevation were largely quartzose. I obtained several specimens of rose quartz, which is very abundant at that height.

The llama and guanaco are both found on the mountain passes; the llama and the mule being used as beasts of burden.

The condor was occasionally seen wheeling above the loftiest summits of the mountains in graceful curves, and on wings that seemed never to tire.

At the latitude of Valparaiso, 33° south, the mountains recede from the coast nearly one hundred miles. The city of Santiago is situated inland, 90 miles from Valparaiso, in the fertile valley of Chili, and in full view of the majestic barrier of the Andes.

I ascended the mountains at this place, and reached an elevation of more than 16,000 feet. The snows were very deep, and the cold intense; but as the air was clear, I could look westward across the plains of Chili rather more than a hundred miles, and out to the shining waters of the Pacific Ocean. Heavy snowstorms raged far below me down the mountain, while I stood in the blue air and brilliant sunshine.

The deep silence of these vast mountain heights, far above the clouds, was most impressive.

At Lota, in 35° south latitude, the Andes recede to their greatest distance from the coast, one hundred and thirty miles. At this point there is a coast range of low hills, varying in elevation from 2,500 to 6,000 feet. I ascended the highest point of these hills, just back of the town of Lota, to an altitude of about 6,000 feet. Before me to the east, the beautiful valley of Chili stretched away, like a mighty panorama, a distance of one hundred and thirty miles. Towns and villages dotted the landscape here and there; some being twenty, fifty, and even a hundred miles distant. Wide and level tracts of prairie, and heavily timbered forests, miles in extent, lay between these scattered towns, The Rio Bio, fed by the melting snows of the Andes, wound its way across the entire valley, like a tortuous silver thread, and poured its considerable flood into the Pacific Ocean, at the base of the hill where I stood.

Beyond the valley, the tremendous wall of the Cordillera reared itself to a height of nearly 20,000 feet, while six stupendous volcanic cones lifted their mighty heads to an elevation of more than 22,000 feet. To the north, Aconcagua stood like a vast sentinel over a wilderness of lofty mountain peaks. Then followed southward the volcanoes of Antuco, Callague, Osorno, Corcovado, and Yanteles.

The magnificent scene was one never to be forgotten. Three of these great peaks were in full activity. Above them by day rose a column of dense black smoke, which gradually diffused itself until it appeared like an enormous feather floating in the air.

By night these volcanoes looked like three monstrous light-houses, casting a deep red, angry, fiery glow upon the white snowy cones about them.

Although these mountains were one hundred and thirty miles distant, the air was so clear that the snows and ridges and chasms on their sides could be seen with the utmost distinctness. They did not appear to be more than twenty miles from the spot where I stood.

As I turned towards the west, the Pacific Ocean, with its long eternal swell of billow coming up from the South Polar Sea, lay before me like a vast expanse of brilliant molten silver.

To the south the great mountain range gradually melted away into the deep blue skies that overhung Western Patagonia.

All about me on the hilltop where I stood grew the laurel *(Kalmia latifolia)*, a low green shrub. These shrubs grow from three to ten feet in height, and form at intervals clumps or thickets.

In these thickets the puma finds a congenial habitat, and under their deep green foliage he often is found lurking. While I was exploring these hills, I came very unexpectedly upon two of these ferocious and dreaded beasts. One of them was caught by the lasso in the hands of my two boy guides, who are very expert with this weapon.

We have seen that at the line of the equator the limit of perpetual snow lies at an altitude of 18,000 feet, or a little more than three miles. We gain from this fact a clear idea of the comparative thinness of the envelope of atmospheric air which is capable of supporting animal life. Below this line animals can live, because the air is sufficiently dense to support pulmonary respiration, and for the conduction of heat from the sun to the surface of the earth. Above this line the air is too rarefied for respiration and the cold too intense to be safely endured by any animal organism.

The elevation of the great mountain systems just described, which occurred in the Pliocene or late Tertiary period, exerted a great influence on the climate of the earth, on the formation of its great rivers, and upon the condition of the ocean. Prior to this time there were no considerable elevations of the earth's crust, and the temperature of the air remained uniformly warm and equable. Now, however, a change occurred. The great elevation of the high mountain ranges intercepted the moisture laden winds from the oceans, and forcing them upward into the colder regions of the air, the moisture became frozen into snow, which rested permanently upon their higher peaks. Lower down the mountain sides the snows were melted by the heat from the sun, and these melted snows formed rivulets, and rivers, and in this way the formation of the great river systems began.

These rivers poured their floods into the oceans.

They did more.

There can be no doubt that the great mountain ranges when first uplifted vastly exceeded their present height. The melting snows and rains, falling for countless ages upon these mountain summits, caused a disintegration and erosion more or less rapid, which in time considerably diminished their altitude. As this disintegrating and eroding process went on, the great stores of *salt* contained in the uplifted mountain crust were dissolved and carried down by the rivers to the sea—and the sea, hitherto of *fresh* and *warm* water, grew gradually *salt* and *cold* by the continual mountain floods poured into it.

It is both reasonable and scientific to believe that the saltness of the ocean does not date earlier than the Pliocene or late Tertiary period, or after the great mountain ranges were uplifted and the great rivers formed.

There is evidence to support this view:

The oceans are not uniformly salt.

The Atlantic contains 25 parts of salt in 1,000 of water.

The Pacific 24 parts to 1,000 of water.

The Indian Ocean 21 parts to 1,000 of water.

The Mediterranean 29 parts to 1,000 of water.

The Black Sea 14 parts to 1,000 of water.

The waters of the Baltic Sea contain but little salt, while those of the Gulf of Finland can be used for potation. The water off the coast of Greenland contains 20 parts of salt to 1,000 of water, and off Cape Horn the proportion is 19 to 1,000.

Near continental sea-coasts and at the mouths of great rivers the waters contain much less salt than farther at sea. The reason of this is that at the mouths of rivers the quantity of fresh water is greater than it is farther out at sea, and the salt is carried down with other sediments by the river currents to a considerable distance from the land. The waters of the Southern Indian Ocean, and the Atlantic Ocean south of the Island of Tristan da Cunha, and the Pacific Ocean southwest of Cape Horn as far as New Zealand, are much fresher than they are under the equator. I have compared the waters in these localities at two different times after an interval of five years, and have found the equatorial waters to contain 3 parts of salt per 1,000 more than the southern seas. This greater saltness was due to a greater degree of evaporation in the warmer oceans. The entire southern latitudes of ocean are fresher than the warmer seas near the equator.

If salt had been poured into the ocean from the beginning of the Devonian period, the water would have contained a much larger percentage than it actually does, and earlier evidences of salt would have been found.

The late Tertiary age saw, then, the formation of the great river systems of the earth,—those systems that have their rise in mountains, and are fed by melting snow. The change exerted upon the temperature of the earth by the mountain uplifts was very slow, and before it was seriously felt sufficient time elapsed to evolve many new forms of animal life.

Our own country seems to have been a congenial *habitat* for these Pliocene animals, for in the Upper Missouri region and in Oregon are vast cemeteries where great numbers of ancient bones are found. The Siwalik Hills in India also contain a great number of fossil bones of this period.

In the Upper Missouri region and along the eastern slope of the Rocky Mountains there have been found the fossil bones of the *camel*, *musk-deer*, *mastodon*, *elephant*, *horse*, *wolf*, *fox*,—while in France, the bones of the *hippopotamus*, *horse*, *deer*, *camel*, and *tapir*, and a species of *bos*, have been discovered. A *rhinoceros* also has been found in France, India, and our own country.

Many of these animals were not unlike the same species of the Miocene age, or that age immediately preceding.

All are unlike any modern species in many important points, and all are now extinct.

The evolution of the **Camel** was, without doubt, from the xiphodon. It needed but a slight change of form on the part of this animal to produce a camel. We are led, however, to inquire into the *nature* of that change and of the causes that led to it.

The fossil camels that I have been able to study were much less completely developed in their osteological structure than are the modern species, and the changes that occurred in the xiphodon to produce them are much less in degree than we would at first suppose. The ancient fossil camel is, in fact, only a modified and more completely developed xiphodon. His size is greater, and, consequently, his legs are longer, his body larger, and his pre-maxillary bones more lengthened.

These are just the changes we should expect in the modified animal. His fundamental anatomy is unchanged, but there is an increased growth of certain anatomical parts, and this growth is induced by a greater nutrition due to an abundant supply of food easily obtained. This greater nutrition determines a growth of parts by an increase of cell elements. Bone cells and tissue cells depend upon nutrition for their growth, and as food was so ample in its supply, and obtained with little effort, the physiological function of nutrition, and consequent cell growth, was easily induced and regularly maintained for a long period of time.

Any change of form, however slight it might be at first, would, in the course of ages, become more marked, and the causes that first led to the change, continuing in force, and added to the power of transmission by the more active and favored individuals, would ultimately lead to the evolution of a new and modified animal form, resembling in some instances its progenitor, and in others being totally dissimilar.

I am not satisfied that there is any evidence to show that the Pliocene camels had a fatty hump on their backs.

Modern camels show no evidence of such a hump in any osteological character presented by their skeleton, and as it is wholly formed out of the soft tissues, and does not affect the bony tissues, it would not affect in any way the bony skeleton.

If the ancient Pliocene camels had a hump, we have no evidence of it.

They can hardly be regarded, then, as anything more than an enlarged xiphodon. One especially important point distinguishes the ancient from the modern camel. The modern species lives in a tropical climate, where the sun's rays pour upon the earth with terrific power. The eye of the camel in its exposed situation would suffer if it were not protected in some way from this fierce glare. Accordingly we find a special provision to meet this end. The supra-orbital ridge, or the bony ridge just above the orbit of the eye, is greatly developed into a projecting margin of bone, which overhangs the sensitive eyeball. This completely shelters and protects the eye from the sun, and the animal is thus enabled to make long journeys exposed to the fierce midday sunlight without danger to this organ.

The skulls of fossil camels show no such bony development of the supra-orbital ridge. And as such a protection to the eye was not needed in the equable temperature of that period, there existed no reason to induce such a special growth of bony tissue. The fossil camels had two toes, but they were ungulated, and not padded.

The cushioned foot of the modern camel is a result of his life upon sandy deserts. As his ancient predecessors with their cloven hoofs walked upon soft and yielding sand, they became in time soft and elastic, through the atrophy of hard hoof tissue, and its gradual replacement by *yellow* elastic fibre and firm *white* fibrous tissue mixed with some muscular fibre and adipose tissue.

It is probable that the stomach of the Pliocene camel was simple, because food and water were abundant. The reticulated stomach and ruminant habits of the modern camel are due to the scarcity of water in its desert haunts, and to the necessity of rapid feeding in its desire to avoid danger. Rapid primary feeding made a second mastication or *rumination* necessary. The development of the **Musk-Deer** of the Pliocene period was similar to that of the camel. We must believe that the xiphodon was his progenitor also, and that his evolution from this ancestor followed along a line closely parallel to that of the camel.

He, too, may be looked upon as a slightly modified xiphodon. The development of the musk-secreting glands was doubtless due in the first instance to some special taste for food of a special aromatic or pungent nature. This special kind of food soon manifested itself in the excretions of the animal, and this special odor, combined with the taste for spicy herbs and shrubs, led these animals to consort more and more together until they formed a community by themselves. The musk glands are dependent upon the alimentary and secretive systems, and are usually located near the inferior or anal orifice of the animal, and in the modern musk-deer this odorous quality is largely dependent upon the nutrition of his body. They differed but little from the xiphodon, the chief points of difference being the development of the musk glands.

The fossil **Elephants** of the Pliocene period followed along the same path of evolution and growth as the mastodon and his great predecessors. As they came in a later age, the long interval between them and the mastodons was sufficient to induce important changes in structure and a more perfect development of anatomical characteristics. They were, however, less complete in structure and physiological function, and presumably in intelligence, than the modern elephants.

In the Pliocene deposits of the Pacific coast have been found the fossil bones of a large **Rhinoceros.**

As far back as the later Eocene deposits, an animal has been found which is probably the first form of rhinoceros that appeared. This early species was without nasal horns. In the Miocene deposits another species of this animal has been discovered differing but little from the early Pliocene type. Besides the rhinoceros there have been found in the same geological horizons several species of a rhinoceros-like animal. These were the **Amynodon** of the Eocene, the **Hyracodon** of the Miocene, and the **Aceratherium** of the Upper Miocene. All these different types were modifications of a single ancestor. This ancestor, as far as we can now determine, was the ancient saurian called the megalosaurus. The rhinoceros was the most highly specialized of any of his allied forms, and he alone has survived, and has transmitted his species to recent times. He was an herbivorous mammal, and lived in large herds in the western part of our own country. From there he migrated to Europe and Asia, where his fossil bones have been found.

If he has descended from the megalosaurus, as there is reason to believe he has, he has become much modified in external form, habits, and modes of life. Such a change of form could easily have taken place in the pre-Pliocene ages, and along a line of diverging development. The changes necessary to transmute one of those saurians to a rhinoceros related chiefly to his osseous and tegumentary systems. His mammalian and herbivorous functions remained the same. All of the Pliocene forms of the rhinoceros are extinct, and but one species has been transmitted to our own time.

It is very probable that the early rhinoceros was more or less aquatic in his habits, and lived by preference near rivers and marshes. But as the ages elapsed he became less aquatic, and preferred a more strictly terrestrial life.

His diet, still wholly vegetable, underwent a change, and instead of feeding on weeds and grasses, he selected shrubs and low bushes. Slight as this may appear, it exerted a strong modifying influence upon his structure.

The effort of feeding upon tough and resisting shrubs and of forcibly tearing their branches, induced in him a feeling of pugnacity, and a determination to overcome difficulties. The tearing of the ground with his nose, or pre-maxilla, to obtain succulent roots, led to an hypertrophy of the skin of the part, until first a slight elevation occurred, and finally an increase of the extra skin growth to a fully formed nasal horn. This horn is wholly tegumentary, but rests upon a bony horn core. The fossil rhinoceroses had two horns situated on horn cores on the strongly developed nasal bone. These horns were always a part of the tegumentary system, and were the result of increased vascularity and cell growth of the skin of that special part. The necessity of overcoming difficulties increased the ferocity of his disposition, and led him to wage war upon his enemies and to protect himself from danger. This again induced an increased growth of his horns, until we find in the modern species an exceedingly formidable and dangerous weapon.

The rhinoceros had well-developed molar or grinding teeth, well adapted to his special coarse vegetable food. He had no canine nor incisor teeth, for the reason that he did not need to hold his food in his grasp, nor did he need to graze upon tender grass. His upper lip was, however, very mobile and prehensile, and enabled him to seize shrubs and bushes with ease.

The rhinoceros has been found in a fossil state over widely extended areas, for they roamed at will during the long ages of the Pliocene period over a land of equable warmth and amid a verdure that covered all the land from the equator to the poles. In the same localities that we find the fossil bones of the rhinoceros we find also the bones of another great mammal—namely, the **Hippopotamus,** or river horse. This great animal was a vegetable feeder and loved to inhabit low, marshy places and the seclusion of river jungles, where he could feed upon the rank weeds and grasses that grow so luxuriantly in such localities. His heavy body is well adapted to an aquatic mode of life, and his dentition fits him to be, as he is, a vegetable scavenger. His great development of subcutaneous adipose tissue buoys his body upon the surface of rivers and marshy lakes, while he devours at leisure the rank vegetation that grows in such places. The megalosaurus, that great terrestrial saurian of the Upper Cretaceous period, may well have been the progenitor of the hippopotamus. Upon comparison, we shall see that he needed to undergo but few important changes, and these could easily occur in the long interval separating the Cretaceous from the Pliocene period. These changes in bodily form were induced by his habits and semi-aquatic modes of life, developing a special form of body to suit a special need.

In the Pliocene period another in the series of horse-like animals appeared, and his fossil bones have also been found in considerable numbers in our western country. This was the **Protohippus,** or hipparion. He was a three-toed animal, about as large as a donkey, and while his feet resembled those of the miohippus, his body had undergone a considerable development.

Still higher up in the Pliocene deposits we find another of these interesting animals. This was the **Pliohippus**, a *one-toed* animal, the other toes existing only as atrophied splint-bones. Here we have an animal with a single toe on each foot, nearly as large as the modern horse, but not quite so perfectly developed as the *true* horse, which was evolved in the next or succeeding age.

All of the vertebrata had two anterior extremities, or arms, and two posterior extremities, or legs, and in all cases both anterior and posterior limbs, as we have seen, terminated in *five* rays of bones, named as follows:

Anterior limbs—carpus, metacarpus, phalanges.

Posterior limbs—tarsus, metatarsus, phalanges.

The carpal bones are small bones to form the wrist, the metacarpal bones and the phalanges are *five* in number and form the hand and fingers.

The tarsal bones are small bones to form the instep of the foot, the metatarsal bones and the phalanges are five in number and form the foot and toes.

This rule is absolute. It never varies from the number five.

If we have an animal with *four* toes on the hind foot as in the hippopotamus, or an animal with *three* toes on the hind foot as in the tapir, or an animal with *two* toes on the hind foot as in the deer, ox, or pig, or an animal with *one* toe on the hind foot as in the modern horse, we may be sure that all the others are present, either as atrophied splint-bones, or rudimentary as small bones, or tegumentary appendages, or partly consolidated with other bones. Whether we have the fin of a fish, the wing of a bird, or the limb of a quadruped, we shall always find the five rows of phalanges either entire, rudimentary, or consolidated.

The principle is constant, the development in different orders of animals may undergo some changes of local form.

The three-toed, horse-like animals of the Pliocene period were a continuation of development of the same series of animals that lived in the preceding ages—namely, the Miocene and the still earlier Eocene. There can be no doubt that all the whole series of horse-like animals descended from a common ancestor, that they were all derived from a common stock. That ancestor could have been no other than the anoplotherium of the early Eocene period.

We have seen that this latter animal varied in size from a fox to a small donkey. The earliest forms were of the smaller size. It needed to undergo but slight changes to be transformed to the first of these horse-like creatures—the **eohippus**—who was himself of no greater size than his progenitor. The anoplotherium, however, had but two toes on his fore-foot, while his successor, the eohippus, had four toes and a rudimentary toe. What was the reason of this?

We have seen that the anoplotherium had but two toes; the others were rudimentary, or in an undeveloped condition.

His mode of life had much to do in determining the development of his foot. He lived at an age when all the conditions of life were especially favorable to the changes that abundant nutrition could bring about.

Vegetation was universal over the earth and was rich and abundant, and the air warm and equable; he was not obliged to make any exertion for his supply of food, nor to seek it at any considerable distance. A continual treading of the foot on soft, grassy pastures, and amid groves of tender trees tended to widen it and to develop the other phalanges that were already in a rudimentary condition.

The surface of the ground exerts a vast influence in developing the form of the animal foot. Soft or yielding ground develops a broad or cushioned foot, while hard stony ground tends to develop a hoofed foot of the simplest character and construction.

An anoplotherium living constantly in the midst of soft rich pastures and quiet groves, taking no violent exercise, and needing no speed to flee from dangerous enemies, would naturally tend to develop a broader surface for the foot to tread upon, and this could only be done by an increased growth of another row of the phalangeal bones, that already existed in an undeveloped or rudimentary state, in the original foot.

These influences would be sufficient to modify the foot of the anoplotherium, and give rise to the eohippus, with a larger number of toes. The entire series of these horse-like animals were slowly modified in point of size, and in the number of their toes. As they developed in size, they became more horse-like, and the number of their toes diminished.

All of them had a slow and awkward gait. But as they had no active enemies, as the great carnivora, they did not need to escape from them by rapid flight, and hence the number of toes atrophied slowly. Toward the close of the Pliocene age, however, these horse-like creatures were confronted by destructive enemies, and to escape from them they were driven to more open and stony ground and unsheltered places. The act of rapid running, in their efforts to escape, naturally and from necessity threw the weight of the body more and more upon the *median digit*, and by the law of *use*, this digit underwent a special development, and the others slowly atrophied or became rudimentary, until finally an animal was evolved with *one* toe—the **Pliohippus.**

This animal was the progenitor of the modern horse, that appeared in the succeeding epoch. The varieties of horse-like animals of still later times, as the zebra, quagga, ass, and tarpan are all derived from the pliohippus.

During the Pliocene period several species of birds, some of which still exist, made their appearance.

Among them are two species of special interest, namely, **Eagles and Vultures.** Both are carnivorous and rapacious birds of large size, and both possess predatory and ferocious habits.

The evolution of the eagle bears some relation to the existence of high mountain ranges. Previous to the upheaval of these mountain chains eagles did not exist, but after their elevation their lofty and inaccessible peaks became a favorite nesting-place for these birds. This induced a special development of a wing capable of supporting the body of the bird in long sustained aërial flight, and hence we see in the fossil bones of these animals, just what we see in the modern species, long bones of a light and porous or cancellous structure, yet possessing sufficient strength to give attachment to powerful pectoral muscles capable of imparting rapid motion to these organs.

Their preference for the more elevated and colder regions of the mountains induced a special growth of the feathers or tegumentary appendages, and this growth was stimulated by a greater nutrition of the body. The fierce and eager carnivorous instincts of the bird led it to seek its prey among the smaller and more defenceless animals, and as these were abundant, the eagle found no difficulty in obtaining an unfailing supply of highly nutritious food.

This abundant nutrition led to a greater development of the eagles, and the species has continued down to our own times.

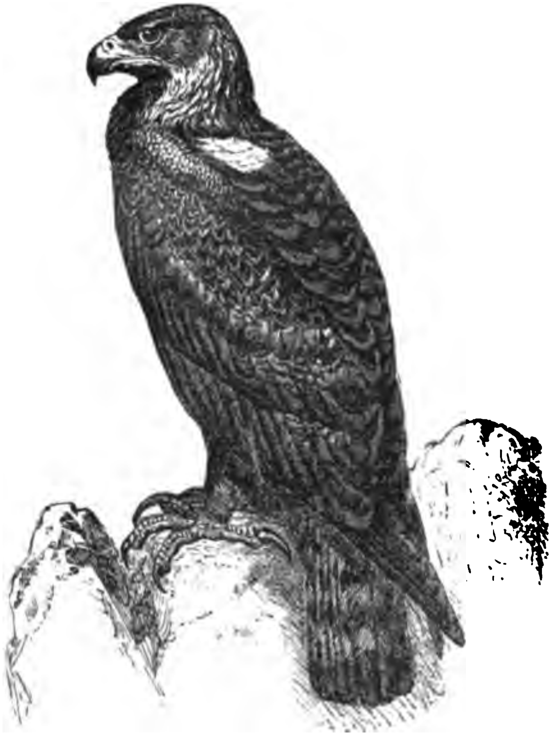


FIG. 73.—MODERN EAGLE.

The curved prehensile beak of these birds is a slow development of both the tegumentary and osseous systems, induced by the long-continued effort of seizing and holding living prey. The development of the talon is due to the same cause, and is a development of the bones of the phalanges and their terminal claw of hard horny tissue, which is of a changed tegumentary character.

The eagles soon developed special characteristics which led them in the course of time to consort more and more with each other, and these characteristics began after a time to be transmitted to their successors, until finally they became so distinctive as to mark the bird as a species differing widely from other birds of prey.

The eagles are solitary in their habits, possessing unrivalled powers of flight, patient of fatigue, fierce and rapacious in their natures, and carnivorous and predatory in their modes of life.

Their strong curved beak and sharp hooked talons are admirably adapted to capture and hold living prey, upon which they solely subsist.

In Fig. 73 we see the modern eagle.

The fossil **Vultures** varied but little from the eagles. In modern times the differences between the two species are more widely marked.

The vultures differed from the eagles in having the beak less curved, and the talons less sharply hooked, while the metatarsal bones and the phalanges were more widely separated. This was due to the habits of the animal. They are scavenger birds, living wholly upon dead animals, which they find upon the ground. This causes them to walk more than the eagles; and, as a result, the foot develops laterally to form a broader surface to tread upon. As they are not compelled to strike their prey, the talon is not specially developed, as in the eagle.

They do not build their nests in such high altitudes as the eagles, and while they possess a large and powerful wing, they seldom soar to any great altitude in flying.

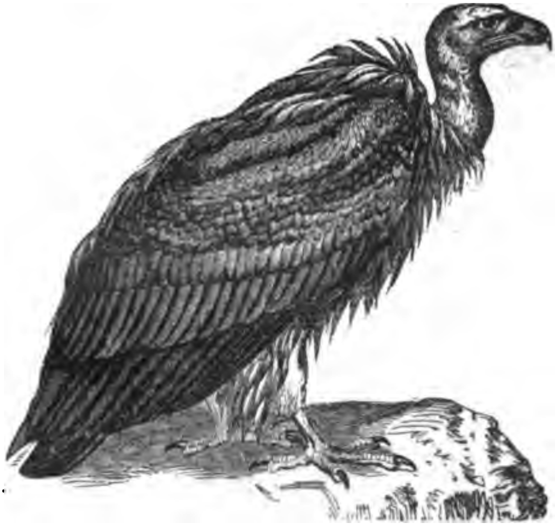


FIG. 74.—MODERN VULTURE.

The modern vulture is a true bird of prey, but he rarely attacks living animals. His habits are those of a scavenger, and he prefers dead to living food.

His mode of life has caused his foot to develop into a form well adapted for walking. His body is large, and supports a powerful wing, and his head and neck are devoid of feathers. We see the vulture in Fig. 74.

By comparing him with the eagle, we see that the points of similarity are so strong as to lead us to the conclusion that he originally sprang from the same ancestor.

The Pliocene period was remarkable for a great number of new forms of mollusks. Many of them are now extinct, while a few have survived to our own time. This form of animal life was exceedingly prolific in that age; and we can judge that it would be so when the natural conditions were so favorable to its development.

In Fig. 75 we see several forms of these ancient mollusks, which closely resemble the modern species. Some are bivalves, resembling the modern oyster, scallop, and clam, while others are univalves, true gasteropods, like the modern snail.

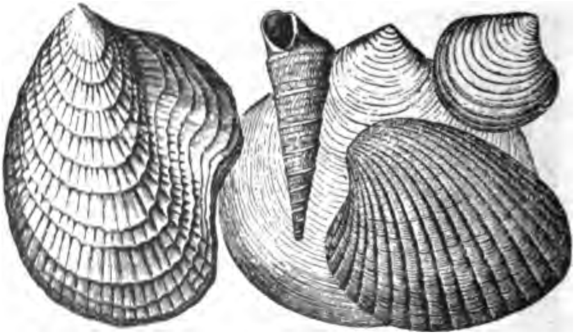


FIG. 75.—MOLLUSKS OF THE PLIOCENE PERIOD.

We have already studied the process of evolution of all mollusks, and have seen that the shells both of bivalves and univalves, however intricate in structure or elaborate in design, are secreted by the little follicles located in the mantle of the animal, out of the lime which the water holds in solution. This lime, when duly mixed with a small quantity of organic matter, also secreted by the animal, is slowly and successively built up into the manifold shapes and beautiful forms so characteristic of molluscan life.

These late Tertiary shells had a wide range of distribution. They were formed in incredible numbers in the seas, just before the great mountain ranges were uplifted, and extended from North America, through the Isthmus of Darien, along the western border of South America, to Southern Patagonia.

They also extended through Europe, into Africa, Persia, and India.

After the great mountain upheavals occurred, these shells were found in vast quantities imbedded in sandstone on the sides and summits of the mountains, at varying altitudes. In the Rocky Mountains they have been found at an elevation of 10,000 feet. On the Isthmus of Darien they form a long line of low ridges, or hills, composed entirely of these shells. The Panama Railway cuts through several of these ridges, at Gatun station, and another at Summit station, the highest point reached by the railway. Here and at Gatun I found many beautiful specimens of these shells, perfectly preserved.

In Fig. 76 we have a view of the Panama Railway crossing the summit of the isthmus at Empire station. On the right of the picture we see a bank cut through by the railway grading. This is filled by these late Tertiary shells, uplifted to their present position by the same forces of internal heat that uplifted the mountains. I dug out of the sandstone at Empire Station several masses of shells which looked almost as fresh, and were as unbroken, as recent specimens.

On the coast of Chili just south of the town of Lota is a high bluff of coarse sandstone. This is worn by the action of the sea and the rains, and presents a perpendicular wall of about thirty feet in height. Out of the face of this bluff is a fossil tree trunk projecting about six feet, and having a diameter of fourteen inches. Both the bark and wood are perfectly petrified. The bluff presents a long, level, unbroken line of sandstone, with a smooth face towards the west. It stretches away to the south for more than a hundred miles, and is finally lost in the irregular coast hills that end abruptly at the island of Chiloe.

These bluffs are covered by overlying beds of fossil shells of varying thickness, and I found them in a perfectly preserved state.

These shells have been found at several points in South America, besides the beds near Lota I have described, and at an altitude of more than 13,000 feet in the Andes. They have been found in the Pyreenes as high as 8,000 feet, in the Alps as high as 10,000 feet, and in the Himalaya range they have been discovered in great numbers at the vast elevation of 18,000 feet.

The *plants* of the Pliocene, or late Tertiary period were nearly the same as we see them now. As the temperature of the earth at that time was universally warm, the palms of a previous age continued to flourish in Europe and Northern Asia. What are now the frozen and inhospitable wilds of Siberia, were in those ages, warm and temperate regions, furnishing abundant pasturage to great numbers of animals. Ample evidence of this fact exists in the great numbers of fossil bones of animals that have been found in those northern regions, and also of the fossil palms and other plants that are now found only in torrid zones.

During the Pliocene or late Tertiary period, the landscape of the earth, and the general outline of con-

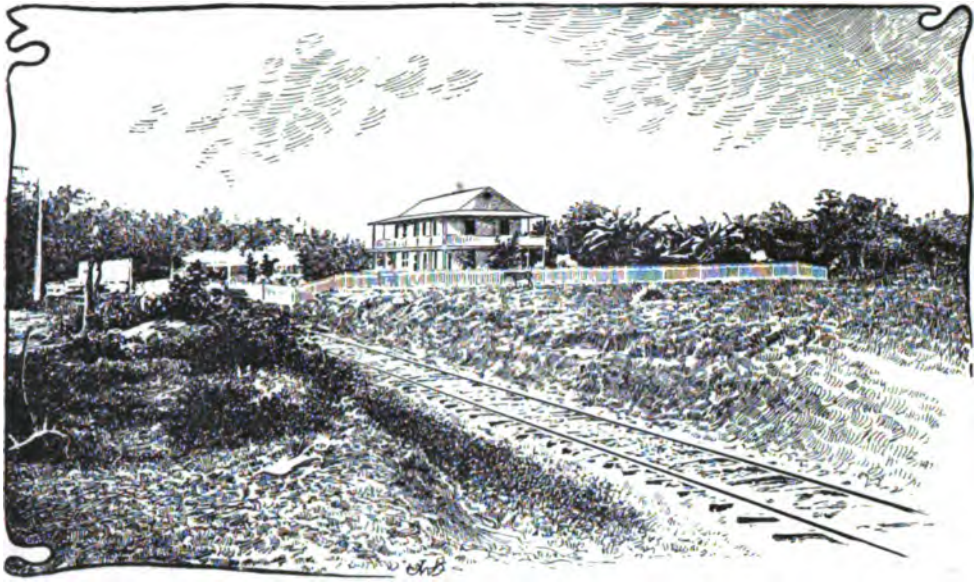


FIG. 76.—PANAMA RAILWAY AT EMPIRE STATION.

tinents underwent some changes. Before the uplift of the great mountain systems, the surface of the earth was comparatively level or undulating. It suffered several slight submergences beneath the sea and subsequent elevations before the great mountain upheavals occurred, and these changes of level occasioned changes more or less serious in the destruction of many forms of animal life. This destruction was, however, mainly confined to the lower forms of life. The higher animals were able to maintain themselves in safety by flight, or the slower process of migration.

North America made some additions to its area by the slow formation of the territory bordering on the Mexican Gulf, and the Peninsula of Florida, and also a long narrow border of land lying along what is now the California coast. But in general the outlines of both North and South America, of Europe, Asia, Africa, and the vast Archipelago of Polynesia, remained practically the same as we see them at the present time.

It seems very probable, as many geologists believe, from the evidence at hand that the continent of North America once terminated in a continuous stretch of islands over what is now the north polar region through to the mainland of Northern Asia, and that all of that great region, which is now an icy or watery waste, was, up to the close of the Pliocene period, a connected land or series of contiguous islands, which formed a congenial habitat for animal life.

These islands forming the great North Polar Archipelago were surrounded by exceedingly shallow waters, so that animals could readily pass from one to another with the greatest freedom.

In our time the land between North America and Asia is nearly continuous, being only separated by the narrow passage known as Behring's Strait. At the close of the Pliocene period, the waters about this entire region, as far south as the group of Aleutian Islands, which form a sort of promontory from Southern Alaska, were very superficial indeed, and it seems probable that dry land once extended over a great part of this area.

The warm and temperate climate that then prevailed, the luxuriant flora that grew everywhere, and the shallow seas and continuous land made the conditions extremely favorable for the free and unrestrained passage of animals from America to Asia, or from either continent to the other.

The same is no doubt true of Southern Asia. The waters are very superficial between the long, narrow point of land known as the Malay Peninsula and the islands of Sumatra, Java, Borneo, Papua, Australia, and New Zealand.

It seems to me extremely probable that this great archipelago, now resting in quiet and shallow seas, was once either connected and continuous land or so nearly so as to allow of the free migration of animals from one part to another.

It is true that Australia is now separated from New Zealand and from Papua by deep seas, but even here the depth is not so great as it is in the Pacific basin proper. Geologists believe that this great area has been the scene of several submergences and elevations.

During or subsequent to the Cretaceous period this might have occurred and the land have been so connected that animals would have found no difficulty in passing from the main continent of Asia to Australia. In cruising about the islands of Java, Sumatra, and Borneo, and especially in sailing through the narrow and shallow Strait of Sunda and the isle-studded Banda Sea, I saw evidences that these islands at some previous geological epoch were joined together, forming a continuous stretch of land as far south as Australia. It is held by geologists that the interior of the continent of Asia is now undergoing a slow upward movement, and that the great South Pacific bed is also slowly rising. It is also believed that a continent once existed over that vast region where there are now only isolated groups of islands, known under the general name of Oceanica. There can be no doubt that there is ample geological evidence to support this view, and if, as I believe is the case, the whole of that vast area was once connected with the main continent of Southern Asia, either as continuous land or closely connected islands, the facts relating to the geographical distribution of animals are capable of easy solution.

The great terminal extremity of the continent of South America, known as Terra del Fuego, is separated from the mainland of Patagonia by the Straits of Magellan. From the first emergence of this continent above the sea in the Azoic age to the Pliocene or late Tertiary period, no such separation existed. The land was continuous to the southerly point of Horn Island. It also extended in an easterly direction to the little group of rocky islands known as the Falkland Isles. There is good reason for believing that these islands were once connected with the main continent of South America by a long, low, narrow strip of land, which has since disappeared by erosion. In the late Tertiary age, when the great mountain range of the Andes was uplifted, the extreme southerly end of the chain was broken off, leaving a deep rift or gorge on the westerly side, into which the waters of the Pacific Ocean flowed.

For many subsequent ages this gorge existed and extended eastward only as far as the plains of Patagonia. These great plains, which formed Eastern Patagonia, extended unbroken to the end of Terra del Fuego, and no strait existed. In the course of time the rains from the eastern slope of the Andes formed a running stream, which extended across these plains and emptied itself into the Atlantic Ocean. This stream slowly formed a channel, which cut deeper and deeper into the land until a passage was opened connecting the mountain rift or gorge on the Pacific side with the waters of the Atlantic Ocean. Now the sea rushed in and cut the passage wider and deeper, and this process of erosion is still going on, aided by the rapid tide which runs on the eastern side at the rate of twelve miles an hour during its ebb and flood. This is the way my own observations have led me to believe the Straits of Magellan were formed.

The land forms a high bluff at the Atlantic entrance to the straits, known as Cape Virgin. The sea from this cape across to the Falkland Isles is extremely shallow, and the evidence is very strong that the land formerly connected them by a long narrow strip which has been washed away, in comparatively recent times, by the action of the winds, the rains, and the sea, leaving them as isolated, rocky islands in the ocean.

In Fig. 77 we have a view of the entrance to the Straits of Magellan from the Atlantic Ocean and of the high bluffs on either side, which are still undergoing erosion from the action of the sea and the weather.

The group of islands bordering on the Caribbean Sea, known as the West India and Windward Islands, were also doubtless connected at some previous geological period. This group comprises the islands of Cuba, Hayti, Jamaica, St. Thomas, and Porto Rico, or the Greater Antilles, and the bow-shaped group of islands, or the Lesser Antilles, ending at the islands of Barbadoes, Grenada, and Tobago, at the extremity of the mainland at Venezuela in South America.

There is abundant reason for believing that this considerable archipelago was at some former period connected with the mainland at Yucatan, at Florida, and at Venezuela, making a semicircular border of land enclosing the deep basin of the Caribbean Sea, and washed on its eastern shore by the Atlantic Ocean.

This extensive area is now occupied by a great number of islands, some of large size, like Cuba, and others mere dots of sand, but all rising out of a clear, blue, *superficial* sea. Most of these islands lie in the Tropic of Cancer, between the 10th parallel of north latitude and the tropical line of 23° 30′. Only a few, belonging to the Bahama group, lie to the north of this torrid line.

My own observations of the geology of this region convince me that this area was once a continuous circular border of land, which served for many ages as a short and convenient highway for the migration of animal life from North to South America. I have studied the greater number of these islands with some care and believe that the evidence warrants this conclusion.

The Yucatan channel is quite narrow, and the depth of the sea is very superficial. The shore on the Yucatan promontory is still undergoing erosion, as is also the extremity of the island of Cuba. Most of the islands comprised in this region show signs of present or former wear.

The close of the Pliocene period saw the surface of the earth closely resembling its present aspect. The

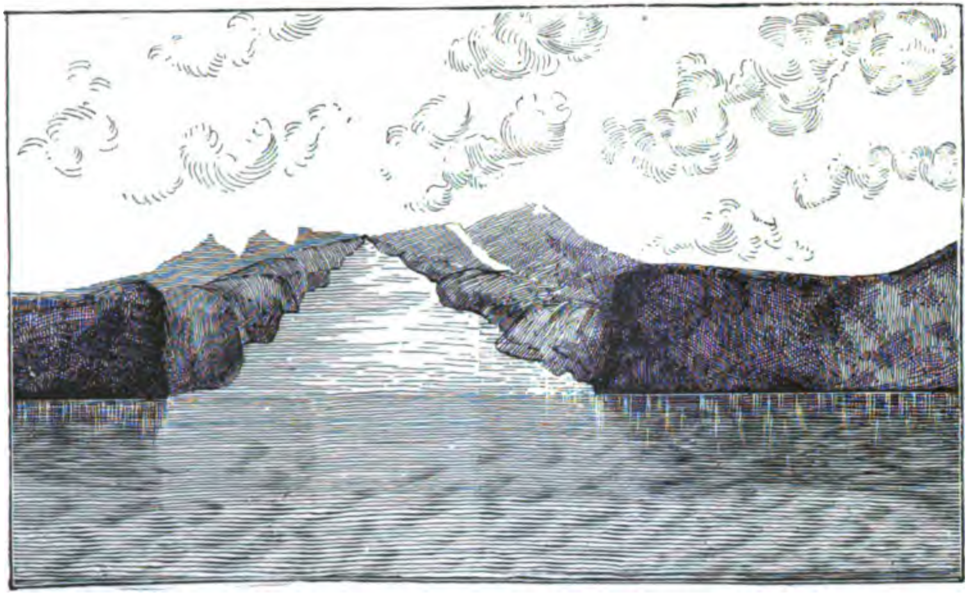


FIG. 77.—CAPE VIRGIN, ATLANTIC ENTRANCE TO THE STRAITS OF MAGELLAN.

changes that have since occurred are those relating to the height of mountain peaks, the more extensive formation of great river systems, and the wear of sea-coasts, the filling up of marshy tracts, and the separation of islands from the main body of continents.

In the long ages of post-Tertiary times, the higher mountain peaks have undergone a considerable amount of erosion through the agency of winds, of frost, snow, and rain. Those high rocky masses have crumbled and worn under the influence of these potent agencies, until their lofty summits have receded to a considerably lower level. This lesser elevation of mountain tops has in turn exerted a modifying influence on climates. When the great mountain ranges were first uplifted, their high crests reached far into the upper regions of cold, and the moisture carried to them from the sea by the winds, caused a prodigious fall of snow. As the snows melted they wore down the higher summits until at length the wear was so considerable that the mean elevation of mountain systems reached a point where they at present appear.

These changes in the altitude of mountain ranges not only cause changes by the washing down of eroded materials, and piling them up into foot-hills or spreading them out over the adjacent land, but by the influences they exert on climates, and the migrations and modifications of animals. In the course of long periods of time, these influences have been potent in causing changes in animal forms.

In the Pliocene deposits there have been found the fossil bones of several species of animals that, while they were fairly well developed, and somewhat numerous, did not, however, survive very long; nor did they become the progenitors of any succeeding race. They

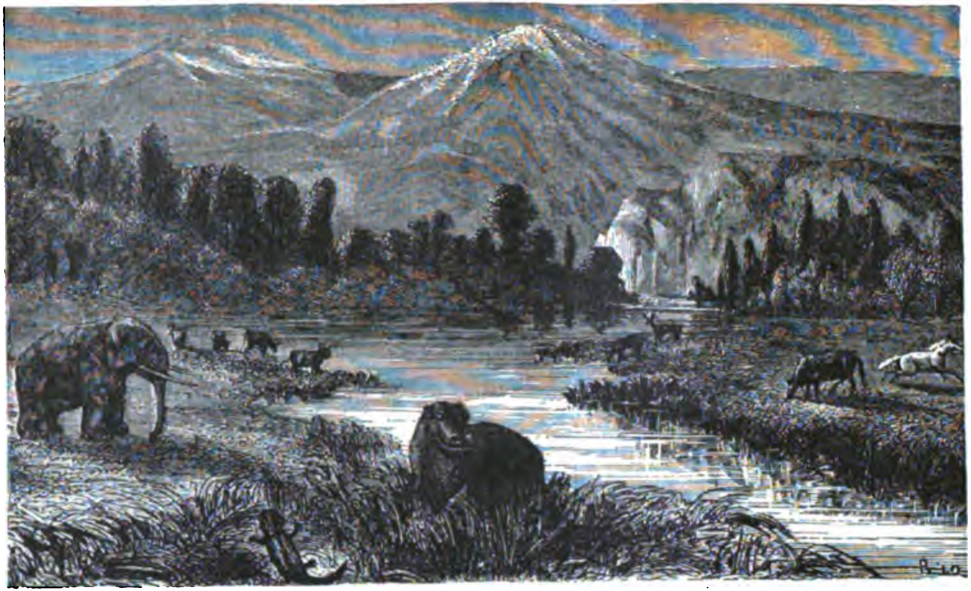


FIG. 78.—IDEAL LANDSCAPE OF THE PLIOCENE PERIOD.

were aberrant types, and, after attaining a more or less complete development, became extinct. Of these were **Oreodon** and **Eporeodon,** two hog-like animals that were herbivorous and ruminating. They had four toes on each foot. Oreodon was about the size of a modern peccary, while eporeodon attained a size nearly double. They were both very numerous on the Pacific slope, and on the eastern slope of the Rocky Mountains. At the close of the Pliocene both disappeared. It is not improbable that these animals were widely diverging forms from the original line of evolution of the hippopotamus, and this view seems entirely reasonable.

Several other aberrant forms appeared in this same geological age, but few if any of them left any permanent successors.

In Pliocene times the true camels began to appear, and our own country seems to have been the cradle in which these animals were evolved. We have already seen that the xiphodon of the Eocene period was unquestionably the progenitor of the camel. In the succeeding ages to the Pliocene period, he had ample time to undergo the slight changes necessary to transmute him to a camel. Henceforth the camel became a permanent organic type.

As the Pliocene period closed, the landscape of the earth was nearly as we see it in our day. Mountains, plains, forests, rivers, and the sea looked then very nearly as they appear now. Some animal forms would have appeared strange to us, and some would have appeared familiar. Such an ideal view is seen in Fig. 78.

CHAPTER XII.

POST-TERTIARY PERIOD:—AGE OF THE GREAT MAMMALS.

The Glacial period—Landscape of the earth—Evolution of carnivora, mammoth, megatherium, mylodon, glyptodon, schistopleuron, bears, lions, tigers, sabre-toothed tiger—Development of a retractile claw—Dun color of skin—Birds—Dinornis—Rodents—Formation of rivers—Plants—Pine—Fir—Spruce—Hemlock—Cedar—Oak—Ash—Beech—Maple—Birch—Rose—Strawberry—Apple—The appearance of the true horse—Influences of the Ice period.

THE last subdivision of the Tertiary period—namely, the Pliocene period—came to an end, and was followed by what is known as the Post-Tertiary period. This epoch witnessed the more complete evolution, and also the final extinction of many of the great forms of mammalian life. Those great forms of animal life that flourished so vigorously in that era—such as the sloths, mammoths, hyenas, lions, tigers, horse-like animals, stags, bears, rhinoceroses, and hippopotamuses—had a wide range over the earth. They extended from the extreme southerly limit of South America over the whole of that continent, through the immense extent of North America, across the arctic islands to Northern Asia, thence onward over that vast continental area to India, Africa, and Australia, comprising all of the dry land over the whole earth. So wide a geographical distribution of these great types of animal life furnishes us with the strongest geological and scientific proof that the physical conditions of the earth were well adapted for their propagation and support. The temperature had not lowered sufficiently to materially change the climate—it was still of a warm and equable character over the whole northern part of the globe. The vast regions of North America bordering on the arctic wilds, and the almost limitless expanse now known as Northern Asia or Siberia, were in those remote ages boundless pastures, rich in verdure, watered by numerous sparkling streams, and basking in warm and agreeable temperature, and lighted by a perpetual summer sun.

These regions were the congenial habitat of vast numbers of herbivorous mammals, who roamed at will over those pleasant pastures where food was so nutritious and abundant.

Such immense herds of peaceful and nearly defenceless animals living quietly amid favorable surroundings, and developing rapidly as to numbers and in anatomical structure, would in turn exert a powerful influence in augmenting the evolution of fierce carnivora, who would find abundant and nutritious food by preying upon them

Accordingly we find that in the rapid development of the herbivorous animals, there is also a rapid development of the carnivorous animals.

Abundant and luxuriant pasturage, giving easy support to immense herds of large and inoffensive mammals like the stag, deer, and mammoth, whose evolution was along the most favorable lines of development and growth, naturally attracted carnivorous beasts of fierce and eager instincts, who found the conditions of life equally easy to them by preying upon such resistless animals. Hence the evolution of the lion and the tiger received a great impulse under conditions so exceedingly favorable, and we find that they attained a great size in the Post-Tertiary epoch, a size that has since greatly diminished until it has reached that of our modern species. We view with interest and perhaps some surprise the rapid anatomical development and growth of the mammals of the Post-Tertiary period. We say *rapid* in a comparative sense, for the duration of this period was of inconceivable extent. All of them—the mammoth, stag, deer, hyena, bear, lion, and tiger—attained a size considerably greater than is now seen in the animals of our time. And the reason of this great size is to be found in the easy conditions of life that then prevailed. An ideal view of the earth at this particular epoch would show us almost limitless expanses of rich and luxuriant field and prairie, of meadow and wood, of hill and valley, watered by plentiful streams, bathed in soft sunshine, basking in a mild temperature, and inhabited by vast numbers of animals of great size and variety, some quiet and peaceful, feeding upon the nutritious and abundant herbage growing everywhere about them so luxuriantly, and following steadily along the special lines of their own paths of evolution, and reaching a high degree of development and growth, through long-continued and ample nourishment. Others of fierce and predatory habits, with natures restless, fiery, and intensely eager, whose carnivorous instincts made them ferocious and cruel, and led them to kill and devour their unarmed and defenceless neighbors.

These favorable conditions of life stimulated a proliferation of tissue cells and an increased growth of anatomical organs, of bone, muscle, cerebral tissue, and a richer and more abundant circulating fluid,—the blood. Hence, under such conditions, animal organizations attained a high development, and greater anatomical growth, as well as more perfect physiological functions. All these great Post-Tertiary mammals are now extinct, and their places are filled by the same species, with a few exceptions, of a lesser size.

One of the most interesting of these great animals was the **Mammoth.**

His evolution proceeded from his great progenitors, the mastodon or the dinotherium, of the Miocene period. If we will refer to these former animals and compare them with the mammoth, we shall see strong points of resemblance between them.

In Fig. 79 we see the mammoth restored. He is a large elephant-like creature, of a heavy anatomical structure, with a trunk or muscular prehensible proboscis, and long powerful tusks *recurved superiorly.*

In the mastodon we have two sets of tusks or canine teeth, which are long, nearly straight, and very powerful, especially those in the upper jaw. The tusks in his lower jaw are less completely developed. What is the reason of this difference in the form of tusk in the two animals, when one, the mastodon, is the progenitor of the other? It is very clear. The mastodon was the evolution of a long previous age—the Miocene. He lived on foliage and roots, and in order to obtain the latter he must dig them out of the ground. His conditions of life were less favorable than those of his successors, and to meet these harder conditions he must develop organs especially adapted to his needs.

Hence the development of his long straight tusk. As time advanced and the vegetation of the earth became more abundant, the animal was not compelled to use his tusks to obtain a supply of food. He could gather grasses and leaves by means of his trunk or proboscis alone, and the long tusks were not needed, but a continual pressure of the tusks upon the ground or against the trunks of trees while the mammoth was in the act of feeding tended to give them an upward curve, in order to place them out of the animal's way. In this manner, then, the straight tusk of the mastodon developed into the upward curved tusk of the mammoth.

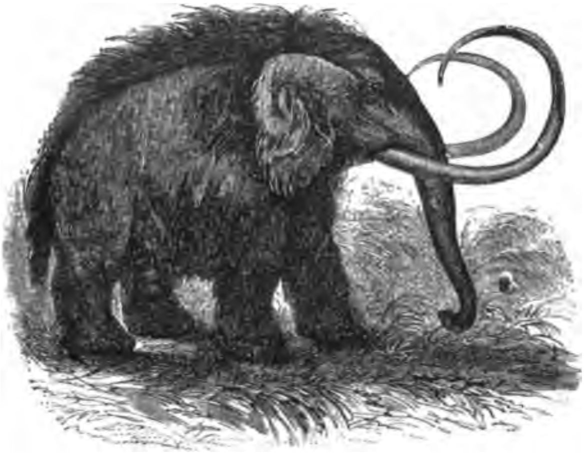


FIG. 79.—MAMMOTH.

The more hairy integument of the mammoth was a superficial character, and was of a later growth in his development. His osteology and his physiological functions did not materially differ from those of his predecessor.

The fossil bones and tusks of the mammoth have been found in great numbers in Northern Asia, in some of the arctic islands, and in the northern part of the Continent of America especially in Alaska, showing that he had a wide range of geographical latitude. This is an additional amount of evidence that these vast regions now lying under perpetual frost and ice were in Post-Tertiary times green and grassy fields, smiling under a continual summer sun, and affording ample sustenance to countless herds of herbivorous mammoths.

Fossil bones of the mastodon have been found in a few localities of South America, along the banks of some of the streams in Paraguay, but no bones of the mammoth have been found there so far as I am aware.

The continent of South America, however, has afforded us the fossil remains of a number of remarkable types of animal life. So far as at present known, these animals have not been found in any other part of the earth. They are the gigantic **Megatherium**, and the **Mylodon**, two edentates, belonging to the sloths, and the **Glyptodon** and **Schistopleuron**, two animals belonging to the armadillos.

In Fig. 80 we have a view of the megatherium, and if we compare him with the mylodon we shall see that the two animals closely resemble each other in their anatomical configuration and structure, while no difference exists in their physiological functions.

These huge creatures found a congenial habitat in the great regions of lower South America, especially south of what is now the tropical line of Capricorn, although then the temperature was uniform to the Pole. To the south of this line stretch the immense level plains known as the pampas. These plains begin at the Atlantic sea-coast on the east and continue on up to the barrier of the high Andes on the west, a distance of nearly a thousand miles in the most northerly part. On the south they terminate at the bluffs that overlook the Straits of Magellan. They extend from north to south about two thousand miles.

From the Cretaceous period to the present time this enormous area has been the home of many diversified types of animal life. In the Post-Tertiary period it has been the early and almost exclusive home of those singular, sloth-like edentates, the *megatherium* and the *mylodon*.

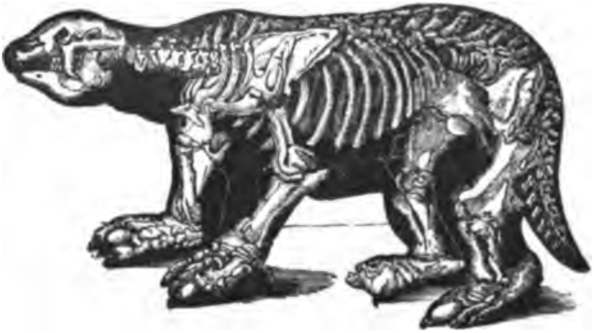


FIG. 80.—MEGATHERIUM.

The evolution of these special forms of animal organisms seems to have been confined to this particular section of South America, although their progenitors undoubtedly migrated originally from North America.

The modern sloth-like animals find their home in the tropical regions of the Amazon River, but their Post-Tertiary ancestors found the great pampas a more congenial habitat. The climate, however, differed but little in those ages over the whole area of South America.

It was universally warm over its whole extent, and the pampas enjoyed a tropical luxuriance of rich vegetation.

These two animal forms were *edentates*, or those having no incisor or canine teeth in either the upper or lower jaw.

They were enormously developed in their osteology. The bony skeleton was greatly in advance over that of any other animal, especially in the size of the femur, tibia, and fibula of the posterior limbs, and the humerus, radius, and ulna of the anterior limbs.

These fossil sloths have been found in great numbers over wide extents of the pampas. Their peculiar anatomical structure excites our interest and leads us at once to study their evolution. What previous animal form was his progenitor?

There appears to be strong evidence that both the megatherium and the mylodon sprang originally from the paleotherium of the early Eocene period.

The paleotherium was a large tapir-like, herbivorous mammal living in vast herds in the fertile and immense plains of North America, and in the almost boundless steppes of Northern Asia.

He found it an easy task in the course of the ages to migrate by slow and easy quiet journeys from North to South America along the border of land that in a previous age formed the great bridge or highway stretching from near Florida along what are now the group of Windward Islands to Venezuela on the South American coast. Along this great highway the paleotherium or his descendants could easily pass and find ultimately the rich and fertile pastures of the pampas.

Here, surrounded by abundant and nutritious herbage, he slowly underwent those anatomical changes that transmuted him into a megatherium or a mylodon. These changes are not so great or so radical as would at first view appear. The degree of change was slight and progressed along lines closely parallel to the original animal. They affected principally his *dentition* and the special development of his digital extremities from a hoof to a heavy claw, adapted to burrowing in the ground.

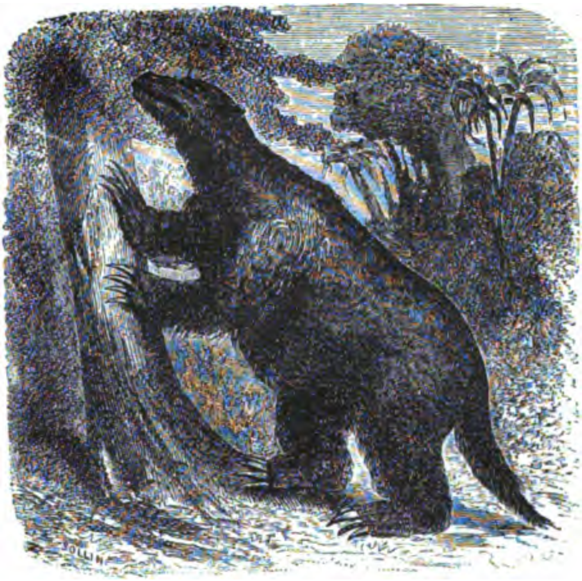


FIG. 81.—MYLODON.

If it is true that both these great animal types were a product of evolution from the Eocene paleotherium, and the conclusion rests on analogy and scientific reason, they needed to undergo but a slight change to pass, in the course of time, from that special animal type to either of the others. The differences between the megatherium and the mylodon are very slight and show a very close parallelism of development from their common ancestor. We have already seen that the paleotherium was a tapir-like animal having a long prehensile lip and imperfectly developed nasal bones, and slightly developed canine and incisor teeth. He transmitted these qualities, as well as his herbivorous habits and mammalian physiological functions, to his successors.

Both the megatherium and the mylodon preserved these special characters, but underwent a further change in an atrophy of their dentition due to disuse, and this disuse was a direct result of their obtaining an abundant supply of food with little effort. The prehensile lip served as an organ to gather the nutritious and succulent herbs and grasses and convey them to the mouth. Once introduced into the buccal cavity they immediately underwent an easy mastication by the molar teeth, and as grazing was not necessary the anterior teeth became in time atrophied, and we have an edentate as a final result.

The most important changes in the evolution of the megatherium and the mylodon was in the digital extremities. The paleotherium had three hoofed toes, the other two remaining rudimentary. In these two animals there were three large toes and one small toe furnished with powerful claws, the fifth toe remaining nearly rudimentary. Considerable as this change in the form of the foot may at first appear, it becomes quite simple when we study it closely.

Both hoofs and claws belong to the tegumentary system, and are developed from it. The habits and modes of life of the paleotherium were such as to develop a foot fitted for free locomotion. He was gregarious and migratory, and this finally evolved a hoofed foot necessary for his special needs. The hard horny hoof covering the extremities of his digits were well adapted for rapid movements over more or less uneven ground, and hence by the law of use we have a hoofed foot specially developed and fitted for the migratory nature of the animal. The habits and modes of life of both the megatherium and the mylodon were entirely different. They were sluggish in their movements, solitary in their natures, and scarcely if at all migratory. By means of the long mobile, prehensile lip, they gathered and conveyed to the mouth the nutritious herbs and grasses upon which they fed, and in consequence the anterior teeth, being no longer needed, finally atrophied through disuse, and disappeared. In order to reach the limbs of trees and feed also upon their tender foliage, these animals acquired the habit of raising themselves on their posterior limbs and drawing the branches within their reach. This, together with the scratching and burrowing habit which they possessed in a slight degree, led ultimately to the pointing of the hard, horny, rounded hoof into a sharp, curved, horny claw. In this way the change from the hoof of the paleotherium to the claw of the megatherium occurred.

The evolution of the megatherium and the mylodon from a common ancestor, the paleotherium, as we have seen, followed along lines very closely parallel. The divergence was slight, and occurred during the slow lapse of great periods of time, and was influenced by external conditions and the transmission of like qualities to favored successors. The general anatomical structure changed but little, while the physiological functions remained the same. These animals in a later age became in their turn the progenitors of the modern sloths, that are now found in the tropical regions bordering on the Amazon River in South America.

The same external conditions of abundant food, of a warm and equable temperature, and immunity from destructive agencies that prevailed in the fertile regions of South America, and that led to the evolution of the megatherium and the mylodon, also led to the evolution and development of two other forms of animal organisms that made their appearance in the Post-Tertiary period. · These were the glyptodon and the schistopleuron.

They were large turtle-like animals, of herbivorous habits, and possessed mammalian physiological functions. They were also edentates like their greater cotemporaries. These two animals could claim without doubt as their progenitors the early land turtles that first appeared in the Triassic period and reappeared in the Eocene period.

They were mammals, enclosed in a thick horny covering or carapace, which was developed from the highly vascular integument.

In Fig. 82 we have a view of the schistopleuron.

By comparing this animal with the glyptodon, we see the anatomical structure is closely similar. The lines of divergence are slight, and relate specially to the arrangement of the plates of integument forming the cuirass, the form of the tail, and the development of the digital extremities.

Both these animals were edentates, and the absence of incisor and canine teeth is to be explained from the fact that they were herbivorous in their habits, and had a mobile and flexible lip and elongated tongue which enabled them to feed without effort on the luxurious herbage about them, and consequently the anterior teeth remained undeveloped.

The tails of both animals were enormously developed, and while this development was doubtless due in part to the habit of rearing their bodies on their posterior extremities, and using the tail to form a tripod of support, it strongly recalls the powerful tails of the earlier saurians, and suggests the idea that the great size of the tail was partly due to the law of transmission from former saurian ancestors.

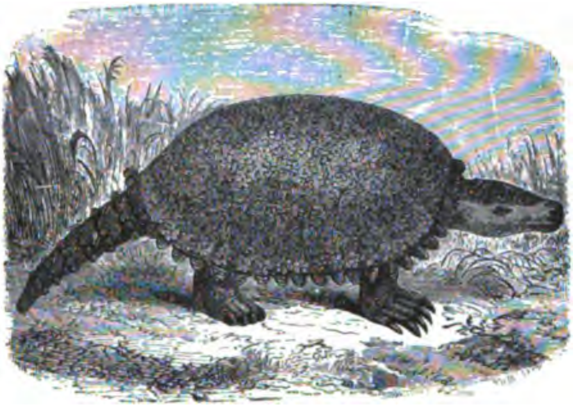


FIG. 82.—SCHISTOPLEURON.

The strong claw of the anterior foot owes its development to the habit of digging and scratching which the animal acquired in its search for roots of plants for food.

Such organisms as the glyptodon and the schistopleuron could not be permanent or widely distributed.

They were of an evanescent or transitory type, and having transmitted certain qualities, which appeared later in the modern armadillos and pangolins, they became extinct.

We find their fossil remains differed in no essential feature from the type of the order of vertebrates. The vertebral column, the bones of the head and of the anterior and posterior extremities were constructed upon the same plan, and had the same number of bones as all the other members of the same order. The differences of size and shape were only adaptations to meet the special habits and modes of life of the animal. They were vertebrated mammals, with a specialized anatomical form, but possessing regular physiological functions.

In several localities in Europe, in Asia, and especially in the northwestern part of our own country, there have been found the fossil bones of the **Lion**, the **Tiger**, and the **Bear**, all belonging to the Post-Tertiary period. These animals greatly exceeded in size their modern successors. They were fierce carnivora, and found an easy subsistence by preying upon their peaceful neighbors. Hence the conditions of life were favorable to a complete and powerful development of these fierce beasts. There was a very close similarity of structure between these three animal forms.

From the observations I have been able to make on their fossil remains, which have been preserved here and in England, I am inclined to think that the anatomical differences between these animals were very slight in the Post-Tertiary epoch.

The form of the skull, the dentition relating to the development of the strong canine teeth, the small incisors, and the sharp cutting edge of the molar teeth, the special form of articulation of the condyle of the lower jaw preventing lateral motion, the form of the pelvis, and the bones of both the anterior and posterior extremities are all strikingly alike. The most marked differences between the osteology of the lion and the tiger, that I have been able to determine, were the slightly greater size of the scapulæ, and the dorsal spinous processes in the former animal.

The anoplotherium of the Eocene period seems to have been, without doubt, the common ancestor of these three special animal forms.

The anoplotherium was an herbivora, while his Post-Tertiary successors, the lion, tiger, and bear, were carnivora. The changes necessary to undergo in order to transmute an herbivorous animal to a carnivorous animal are both anatomical and physiological.

We have already seen that the dogs and hyenas, both of carnivorous habits, were also evolved from the anoplotherium. But while they were carnivorous they were not predatory and destructive. They did not kill other animals for food, they only subsisted on animals previously dead. The bears preceded in order of evolution the lions and tigers. They slowly changed, and retained in a partial degree herbivorous habits. In their search for food they could eat many vegetable substances as well as animal flesh, and hence they are not solely carnivora. They developed canine teeth, and these, with the molars, could cut and masticate a mixed food.

They had a non-retractile claw which was only fitted for digging and scratching, and could not be used for prehensile purposes. They were an intermediate order of evolution between animals strictly herbivorous and those strictly carnivorous.

They were *plantigrades*—animals walking flatly on the plantar surface of the foot—the whole foot coming in contact with the ground.

They were slightly in advance, in point of development, of the herbivorous animals. The latter used both anterior and posterior extremities solely for locomotion. The bears used the anterior limbs partly for holding food while in the act of feeding.

The lions and tigers were still more advanced in the scale of evolution. While they used all their limbs for the purpose of locomotion, this act was not rapid, as it was in the *hoofed* animals. It was more of a stealthy, creeping tread, and the strongly developed posterior gluteal muscles were specially adapted to enable the animal to spring upon his victim. The anterior limbs became prehensile organs and this special use places them in advance of animals whose limbs are purely locomotory.

The huge lions and tigers of the Post-Tertiary period, having the anoplotherium of the Eocene age as a common progenitor, followed a line of evolution and descent which has shown but a slight tendency to diverge, even to our own time. They are strikingly alike in structure. What led to their special evolution from an ancestor so unlike them in many anatomical points?

It is probable that in the course of ages some of the anoplotheria developed a tendency to diverge in form and to become more specialized. Some of these developed a tendency to wander away and seek by preference sandy and desert regions. A long continuance of a life in such localities, inevitably impressed a change upon the animal. The original hoofed foot slowly changed to a cushioned foot with a muscular pad where it came in contact with the yielding sandy ground. At the same time a scarcity of vegetable food led the animal to seek better subsistence, and this was found in the habit which he gradually developed of seizing small prey and feeding upon it. As this predatory habit increased, and he had need to *hold* as well as *seize* his prey, the canine teeth, which were a fundamental part of his organism, became developed by degrees, until in the Post-Tertiary age they developed into sharp and powerful weapons. This great development of a canine tooth is seen in the fossil remains of *machairodus*, or sabre-toothed tiger. This terrible carnivor had the superior canine teeth developed into a sharp-pointed flattened weapon, like the slightly curved end of a broad-sword. He followed the huge edentates to South America in their migrations, and the ungulates northward to Asia and thence to Europe. The cushioned foot of the lions and tigers had five toes, while the hoof of their ancestors had several of the toes in a rudimentary state. But now the new animals, under a special use, developed them all, and the terminal ancestral hoof slowly changed to a sharp claw. A peculiar condition of the claw of the *Felidæ* is that it is *retractile*. A special muscular apparatus was at length developed to provide for this, and here a tendency to develop a *special apparatus* to meet a *special need* was powerfully stimulated by the law of use. As the animal had need of a prehensile claw to enable him to seize living prey, the terminal tegumentary horny tissue became developed by increased cellular growth into a sharp curved claw pointing downward. As the animal was a true digitigrade, walking upon the tips of his toes, this downward curved claw impeded his locomotory movements, and he made a necessary effort to lift it up out of the way. By this effort long continued, he at length developed an *extensor muscle*, or bundle of muscular fibres, out of the digital extensor muscles, which served to retract the claw and conceal it by the side of the plantar cushion out of which it grows by the process of cell elaboration. This arrangement of curved claw and retractile muscle has been transmitted to modern species, and is now seen in all the genus *Felis*.

It is probable that all animals that have successively appeared upon the earth had a uniformly dun-colored skin. This appears to have been the universal and natural hue of the skin before hair or fur was developed. And in later ages when hair appeared upon the skins of animals, it had the same dun color. Most feral and some domestic animals still preserve the same hue. The colors and markings of some modern animals are due to climatic influences, and to what is called *mimicry*, which gives rise to the formation of special pigment cells in the hair follicles of the skin.

This uniform dun color prevailed among the earliest saurians, and has continued to be almost uninterruptedly a standard type of hue among most of the animals that have since appeared upon the earth. Even modern animals with brightly colored hair have the *skin tissue* dun-colored.

Birds were also found in considerable numbers in the Post-Tertiary period. Among them was one of gigantic size, the **Dinornis**. This was a sort of ostrich, and from the few bones that have been found in South America, in our own country and in Europe, it is probable that he was an animal bearing some resemblance to both a stork and an ostrich. The bones are of great size. The tibia of one measured three feet in length, while the extremely elongated growth of his seven cervical vertebræ gave his neck an extraordinary length. He was probably the progenitor of the modern ostrich and of the storks and flamingoes.

Other forms of Post-Tertiary animals besides those above mentioned lived and flourished in great numbers. The rodents, as the **Beaver, Otter, Squirrel,** and **Rat,** found a congenial habitat over widely scattered areas. All these special forms of life are variations from one, the beaver of the Tertiary period. This animal has the special characteristic of being able to gnaw woody fibre by means of a peculiarly developed incisor tooth. The animal, an herbivor, found a delight in gnawing the limbs and trunks of trees and shrubs, partly for food, and partly to construct a place of refuge from his enemies. To do this, he must use his incisor teeth, which up to this time were simple teeth used only to cut or incise the simplest substances. Now under the stimulus of a new use to meet a special need, an increased vascularity of the part is set into activity, and a new growth of the root of the tooth is developed. Coincidently with this is a new development of the lower jaw to accommodate the new tooth. The act of gnawing, long-continued, gives to the tooth a curve to meet its fellow of the other jaw, and we finally have a long deep-set tooth capable of growing from the matrix and renewing itself as it is worn at the point.

All the rodents possess this special form of tooth.

In the Post-Tertiary period the evolution of the *true horse* occurred. We have already seen that the first of the horse-like animals, the eohippus, appeared in the Eocene period. It was a small animal, no larger than a fox, and had four toes on each fore-foot and three toes behind. In seems very probable that the anoplotherium of the early Eocene age was his progenitor. Following him in point of evolution and higher development came the orohippus and the epihippus. In the succeeding Miocene period the mesohippus appeared, the next later and the next higher horse-like animal. Miohippus came after him, still more specialized in his anatomical growth. These two, in the horse-like series, filled the gap in the Miocene age, but in the Pliocene age a still higher form appeared upon the scene—the protohippus. He had three toes on each foot, and he was nearly as large as a donkey in size. From this time forward the evolution of these horse-like creatures was rapid, for at the close of the Pliocene period we find another form, with a single toe only, the others being undeveloped and rudimentary. This was the pliohippus. During the succeeding ages he gradually changed and reached a point of more perfect anatomical development until, in the dawn of the Post-Tertiary age, the *true horse* emerged, and the long line of equine evolution is complete. Our great western country, bordering on that region where the Rocky Mountain range now stands, was the original home of the horse and his predecessors. After his evolution was complete, and he became a highly developed animal of special form and great speed, he migrated to the north, across the bridge of land where Behring Strait now is into Asia, where for ages he lived in a feral state. He also migrated to the south, probably along the highway of Darien's Isthmus, until he reached the almost limitless pampas of South America, and here he roamed at will until the evolution of an animal that appeared in a later age, put a bit in his mouth, and scarred his flanks with an iron spur.

In his own land he became extinct, and North America was without the horse until he was re-introduced, in a modern age, by a race of biped animals, not strictly *feral*, but far more ferocious.

In Fig. 82½ we see the various steps in the evolution of the horse.

In the Yale Museum at New Haven, Conn., are many beautiful specimens of fossil polydactyl horses.

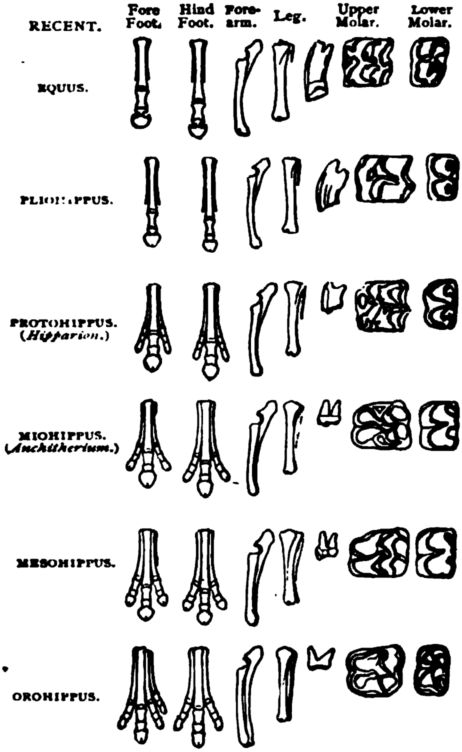


FIG. 82½.—EVOLUTION OF THE HORSE

If we take a general view of the earth in the Post-Tertiary period we shall see that the outlines of the great continental areas have undergone but comparatively slight changes from the preceding ages.

The great mountain systems are completed. No new upheavals of any importance have occurred. The Andes, the Rocky Mountains, the Himalayas, and the other ranges of lesser altitude and extent remain tranquil and unchanged, except the inevitable erosion from wind, snow, and rain. The loftiest of these uplifted masses bear to the mass of the earth itself, as we have already seen, the proportion of a marrowfat pea to a fifteen-inch globe, a size that is inappreciable when viewed from a considerable distance.

The Post-Tertiary age was eminently the era of the great river systems of the earth. These river systems owe their existence to the great mountain systems. As the great mountain ranges of the earth were completed in this period, so the great rivers became completed also.

In North America the St. Lawrence River, the Hudson, Mississippi and Missouri, the Ohio, the Colorado, with its mighty *cañon*, and the Columbia attained to nearly their present dimensions.

In South America the Magdalena, the Orinoco, the Amazon, the La Plata, and the Negro became the great watercourses as we now see them.

In Europe the Rhine and the Danube. In Asia the Indus, the Ganges, the Yang-tse-Kiang, and the Amoor. In Africa the Nile and the Congo all reached in that age the condition nearly as we now see them. While these great rivers have undergone some changes due to riparian erosion, and the cutting down of rocky beds, as well as the formation of deltas, their course and general direction have been remarkably stable throughout the ages. The special reason for the formation of these great rivers was the great elevation of the mountain ranges. Their lofty summits reached far into the regions of perpetual cold and acted as a barrier to intercept the moisture-laden winds from the oceans. This moisture, being forced upwards, was precipitated upon the mountain tops in the form of snow and rain. The long, sloping sides of the mountains caused the rains and melting snows to form into rills and rivulets, and these uniting, ultimately formed the great rivers that found at length their way back to the sea.

The rays of the sun, the cold and lofty mountain summits, and the sloping mountain sides were the cause of the formation of the great rivers of the earth.

The flora of the Post-Tertiary period presents many forms of plant, shrub, and tree that gladden our own landscape. In the plant world, as in the animal world, we see lines of descent, or types, where plants have developed along lines very closely parallel.

In that age flourished the pine, fir, spruce, hemlock, and cedar belonging to the conifers of the Carboniferous age. There were the oak, ash, beech, maple, and birch of closer grain and more compact woody texture, owing to the influence of dryer air and soil and clear sunlight, giving greater cell-growth. Among flowers have been found the *Rose*, which afterwards developed into the *Strawberry*, and later still into the *Apple*, forming the beautiful and useful order of the Rosaceæ or roseworts. Many other forms of plant life have been found, showing that climate influences were as favorable to the development of plant life as to animal life.

While the great continental areas of the earth became completed in their extent in the Post-Tertiary period, and the mountains reached their loftiest heights, while the rivers channelled their way to the sea, and the land everywhere was ornamented with flower, tree, and forest, the grandest climax of all was the culmination of the great types of mammalian life. We have already seen how exceedingly favorable the conditions of life were to the development of the greatest forms of animal organisms. During that age the whole earth formed a congenial habitat to the vast numbers of animals that freely roamed at will over its entire extent. The food found everywhere so abundantly was the chief cause in producing animals of such large size. In proportion as food was ample, nutritious, and easily obtained, *cell proliferation* was rapid, and anatomical growth augmented. And these conditions being present, the long ages of the Post-Tertiary period saw the highest development of animal life that has ever appeared upon the earth.

The carnivors, the herbivors, the edentates, and the marsupials ran a sort of luxuriant riot, and under such favoring influences became exceedingly numerous and attained an enormous size. The vast and rich pasturages of the earth fairly swarmed with these gigantic animal organisms. As the ages of the Post-Tertiary period drew to a close, and the first gray dawn of the succeeding age tinted the geological horizon, a *selection of habitat* began to appear among the various types of animal life.

The marsupials found life congenial in the almost limitless expanses of what is now know as Australia, and the subsequent isolation of that nearly continental area by the breaking up into islands of the land intervening between that and the mainland of what is now Asia, has served to perpetuate to our own time those interesting animals that stood in the Jurassic period as a connecting link between the great herbivorous saurians and the next succeeding animal form—namely, the mammals.

The edentates found a congenial habitat in the boundless pampas of South America. Here, amid a never failing supply of rich food, these ponderous animals underwent the transmutations so peculiar to their special anatomy.

North America, stretching away so magnificently from the Mexican Gulf to the North Pole, across the arctic islands into Northern Asia, then basking under a perpetual summer sun, afforded ample and generous pasturage to vast herds of herbivorous animals that wandered free and uncontrolled over those immense extents of wood and prairie, where every favorable element combined to produce those ponderous animal organisms.

Asia, affording almost half of the dry land of the earth, gave an agreeable refuge to hosts of fierce and predatory carnivorous beasts, who attained an astonishing anatomical size by fattening upon defenceless neighbors. The immense and sequestered regions of Central and Southern Asia, with its desert, wood, and jungle, seems to have been a favorite hunting-ground for these dangerous beasts who delighted to prey upon living animals.

This selection of habitat, which characterized the later ages of the Post-Tertiary period, has come down to our own time, and we find in the present age the same forms of animal life occupying the same continental areas.

As the Post-Tertiary age drew to a close, the great animal types that were so distinctive and characteristic of it gradually passed away and became extinct. None of those huge and exuberant animal forms now exist. The great fossil cemeteries of Asia, Europe, North America, and South America yield us their bones, and from these we read the interesting and unerring story of their evolution and their life.

Science has reconstructed these animals from their perfect fossil remains, and restored their outlines, and we can read as from a book the course of their evolution from preceding forms, their habits and modes of life, their transmission of character, and their final extinction, with the greatest clearness and precision.

Their history lies before us like an open book, and as we turn its geological leaves we read the whole story of the immense past with clearness and certainty.

Most of the forms of molluscan life that flourished in the Post-Tertiary period have survived to our own time, and are found upon the earth to-day.

Finding their habitat chiefly in the sea, they have escaped the destructive influences of changes of level of the surface of the land, and have escaped also the influences of a change in climate.

THE GLACIAL EPOCH.

During the Tertiary period, and extending into the Post-Tertiary period, several oscillations of level occurred over a part of some of the continental surfaces. According to the best geological data, these changes of level principally occurred in the northern part of North America, in the great Arctic Archipelago, and on the borders of Northern Asia. The change consisted of an upward movement of the earth's crust, followed by some partial subsidences, and again an upward movement. The cause of these oscillations of level of the earth's crust was the operation of internal terrestrial force acting with sufficient power to raise or depress the crust according to the activity of the force.

A rise of level of a continental surface would exert a powerful influence upon its temperature, and when this rise of level amounted to even a few thousand feet the effect would be strongly felt.

We have seen that at this particular period all the great mountain systems of the earth were completed. They had reached their loftiest altitudes, and had penetrated into the regions of perpetual cold. While their summits were snow-clad, their sides and bases were still within a range of temperature fitted to support a luxuriant vegetation.

In the course of time, however, these lofty mountain summits exerted an influence upon the temperature of their immediate vicinities. The winds, laden with moisture from the sea, were carried along towards these mountain barriers, and, being intercepted in their course, were forced upward into regions of severe cold. Here the moisture was condensed, and fell in the form of snow upon their summits. The snow-covered peaks lying above the perpetual snow line exerted a cooling influence upon the air about them, and this influence was most strongly marked in the higher northern latitudes. The mountains nearer the equator exerted a less powerful cooling influence.

During the later ages of the Post-Tertiary period the cooling influence of the northern mountains was strongly felt, and at length a distinct *climate* was produced in those regions bordering upon the Arctic Archipelago.

The rise of level of the surface of those regions, which geological researches have demonstrated, was sufficient to induce heavy snowfalls, and at last a perpetual winter set in, which has continued to our own time.

This arctic winter, with its deep and continuous snows and severe cold extending over a great area where once great herds of animals found a rich pasturage, was very destructive to animal life, and exerted besides a very powerful influence in the geographical re-distribution of that animal life.

Many forms, as the mammoth and the mastodon, perished; other forms, as the carnivora, who delight in a warm climate, were driven to more southerly latitudes, until in Southern Asia and Africa they found a congenial temperature. Here the conditions of life were less favorable to them.

So many great herbivorous animals upon which they had preyed for countless ages having been destroyed in the severe cold, they found food less abundant and more difficult to obtain, and, by a reversal of the law that led to their enormous development through abundant and easily obtained food, they slowly underwent a retrograde change until they—by a process of cell-atrophy, or non-development through lesser nutrition—reached the lesser size that they now present.

This is the reason that the lion, tiger, panther, bear, and hyena, that were so greatly developed anatomically in the Post-Tertiary period, became smaller in size in the Quaternary age.

They followed a simple but retrograde law that harder conditions of life, where the struggle for existence is greater, cause a less rapid cell-development and growth, and, in the course of time, an atrophy of anatomical organs.

CHAPTER XIII.

THE POST-TERTIARY PERIOD:—THE AGE OF MODERN FORMS OF LIFE.

The Quaternary period—Résumé of the origin of life—Formation of permanent climates—Distribution of groups of animals — Sloths — Armadillos — Pangolins — Ai—Unau—Puma — Sheep — Llama — Guanaco — Ostriches — Emus — Storks—Cassowaries — Boa— Alligators—Toucans—Parrots — Humming-birds — Prehensile-tailed apes — Howlers — Spider monkeys—Barrigudo—Cai—Marmosets—Tamarins —Condor — Insect life — Bees —Wasps — Ants — Beetles — Hornets—Flies—Foraging ants — Peccary—Tapir—White-lipped peccary—Capybara—Wild boar—Bats—Bisons—Yak Anoa — Giraffe — Antelopes — Rumination — Musk-ox — Prong-horn antelope—Elk—Deer —Wolves—Foxes—Jackals — Dogs — Gray wolf — Coyote — Bears — Polar bear — Varieties of bears — Beaver — Musk-rat — Prairie-dog — Striped gopher — Hare.

In the preceding chapters we have passed in review the more important phenomena in the evolution of life that have occurred upon the earth. These phenomena are the origin and progress of life, and the successive geological changes that have occurred in the earth's crust.

We have seen that the peculiar vital principle we call *life* had its origin in a little mass of albuminous protoplasm—a cell—which was formed by the union of certain simple elements, under the influence of *chemical energy* or *force*, which acted upon those elements in the quiet waters of the Silurian seas.

This little protoplasmic cell had the power developed within itself to divide into other cells and of transmitting to them the same power of subdivision. It had also the further power of *nutrition* and *growth.* These little cells soon acquired another power—that of aggregating into masses and of developing a tendency for some of them to do a *special* thing, and under the influence of this tendency to take upon themselves a certain kind of work, and, by a physiological division of labor, to become organized bodies of more complex structure and of higher powers.

In this way life first appeared upon the earth.

We have already admitted this view of the origin of life as scientific and correct, and, having once admitted it and accepted it as a truth, we can go on and explain the evolution and development of all the forms of life that have successively appeared upon the earth from the *first cell* up to *man.* We have seen that the first simple animals composed of a single cell were followed by those composed of groups of cells, which attached themselves to the rocks by a footstalk. From these groups came sponges, the lingula, and the early crustaceans. These again were succeeded by strings of cells, from which were evolved the marine worms, having a free and independent movement in the water. The Silurian age was the scene of evolution of these earliest forms of life, and they were all simple and lowly organisms.

In the succeeding era, the Devonian age, we see a higher step in the scale of life, the evolution of fishes, the first of the vertebrates. In the following age reptilian life appeared, and the primitive seas swarmed with those huge and strange appearing monsters. An intermediate form of animal life followed the reptiles, and connected them with the mammals. These were the marsupials. From them came the evolution of the true mammals. During all this great lapse of time—the flight of these countless ages—the earth itself underwent important changes of extent of area, of level, and of the appearance and evolution of vegetable life, and became more completely adapted to support animal life. As the atmosphere became clearer, and the land area greater, and vegetation more abundant, animal life evolved more rapidly and advanced to a higher grade of development and diverged from original types. No important advance could take place in the development of the higher forms of life unless the earth itself advanced and provided a fitting habitat for these higher forms. The evolution of the earth and the growth of *plant life* must precede the evolution and growth of *animal life.*

Before mammals, with warm blood and air-respiring lungs, could live, the earth must furnish an atmosphere of pure air, and also proper nourishment for the support of animal life, and hence followed terrestrial changes which made the earth a fitting abode for the most advanced forms of animal life.

Until within a comparatively recent period the *whole* earth furnished an agreeable dwelling-place for great numbers of animals of large size, and of species now unknown to us. A warm temperature, abundant food, and freedom of migration were favorable conditions for the evolution of the higher forms of animal life. We find these higher forms widely distributed, from the southern capes of South America, of Africa and of Asia, to the north pole. Everywhere they enjoyed all the conditions that favored the highest development and growth of anatomical structure.

These conditions continued until in the Post-Tertiary period animal life reached its highest point of evolution and development. The mammals of that age reached a degree of anatomical growth that made them the giants of the ancient animal world. They were indeed the monarchs and masters of the earth.

At last a change came. The northern regions of the earth, that had so long basked under a continual summer sun and gave sustenance to myriads of great mammals, now became buried under a vast layer of snow and ice, and the Glacial period became a great sepulchre for millions of organisms that were a short while before instinct with life.

This period of destructive cold changed the face of the northern regions of the earth, and caused a migration to warmer zones of many animals that formerly found a home there.

Many others found a grave in the icy shroud that covered the land, and ultimately became extinct.

After the Glacial period had passed away and the limits of cold had been fixed in the northern latitudes, the earth entered upon the phase of its existence as we see it now, with its climates and seasons, and its zones of varying temperature. The more torrid regions were now fixed permanently near the centre of the earth's surface. To the far south lay vast wastes of ocean, whose polar waters were locked in icy fetters. To the far north the archipelago of the arctic islands were buried under a mantle of snow forbidding the approach of animal life.

The temperate and torrid regions alone gave a habitat to animal organisms. Under these new climatic conditions groups of animals began to arrange themselves permanently in special localities, some seeking the more torrid zones, as the carnivora, others preferring the cooler latitudes, as the herbivora. In South America the great edentates of the Post-Tertiary period now became extinct, and in their place the sloths appeared. It is probable that the modern sloths that now inhabit the great forests bordering on the Amazon River are evolved from the megatherium and mylodon.

This is true also of the **Armadillos** and the **Pangolins.**

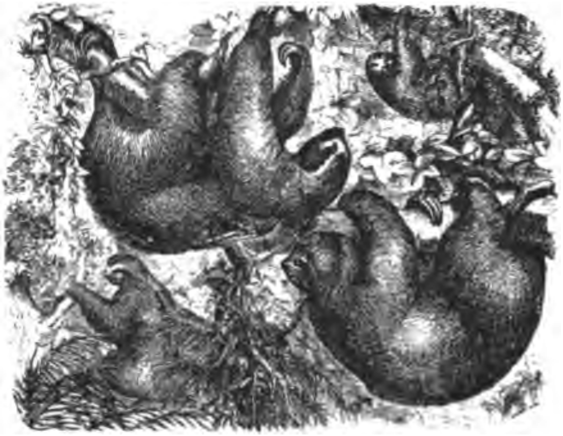


FIG. 83.—GROUP OF MODERN SLOTHS.

The sloths, armadillos, and pangolins are edentates like their progenitors. They have thick cuirassed skins and long curved claws. While they retain many ancestral traits, and have undergone but slight changes in development, they are more advanced in some special characteristics.

The Post-Tertiary edentates—the megatherium and the mylodon—were animals of great size and lived on the ground. The modern sloths are arboreal in their habits, living almost wholly among the branches of trees. They are much smaller in size, and their long curved claws are admirably adapted for their special mode of life.

In Fig. 83 we see a group of these animals. There are at present two species of sloth. The three-toed sloth, or the **Ai**, and the two-toed sloth, or **Unau.** The other points of difference are very slight and in both these species the remaining bones of the toes are rudimentary.

These animals clearly point to a retrograde development in mammalian life. Most of the animals of the Quaternary period show a retrogression in evolution.

In the Post-Tertiary period mammalian life reached its climax in size and numbers. The whole earth teemed with exuberant life. All animal organisms far exceeded in their development any that have since appeared. After the subsidence of the Ice age, and the earth had assumed its present aspect, a retrograde movement was seen. Great areas of the earth, where once were fertile pastures, now became arid or frozen regions incapable of supporting life. Food was less abundant, climates were severe, and forced animals into more restricted areas, destructive enemies were closer at hand, and these harder conditions made life more difficult, and in proportion as life was less luxuriant and harder to defend and maintain, development was less rapid, until finally a retrogression was observed.

This retrogression in point of anatomical growth is clearly seen when we compare the sloths of South America with their great ancestors, the megatherium and the mylodon. The sloths are edentates like their progenitors, but are a degenerate race in point of evolution.

A further instance of this degeneration of species is seen in the armadillos. They are edentates that appeared in the Quaternary period, and are without doubt descendants of the schistopleuron and the glyptodon of a previous age.

The cuirassed plates of integument, the edentate maxillary bones, and the special development of strong sharp claws closely connect them with the Post-Tertiary species.

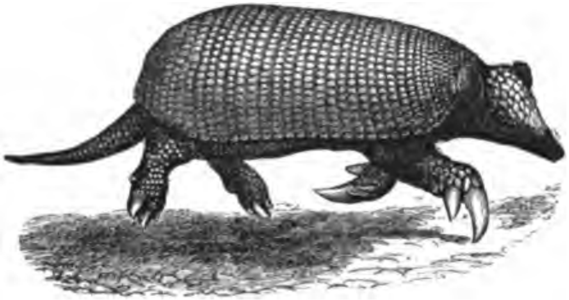


FIG. 84.—GREAT ARMADILLO.

There is a very close parallelism of structure and development between the schistopleuron and the modern armadillo.

We see this modern animal in Fig. 84.

The **Pumas** of South America are a lesser development of the great *Felidæ*, the lions and tigers of the Post-Tertiary period. They are not numerous, owing to the harder conditions of life they now encounter.

We have seen that the xiphodon of the Eocene period ranked as the progenitor of many later forms of animal life. Among these divergent forms are the deer, elks, camels, giraffes, and the sheep, goats, llamas, and guanacos.

All these animals have followed their diverging lines of evolution, in the Post-Tertiary and Quaternary periods, and have continued to our own time. The vast plains of Chili and Patagonia furnish a pasturage for great numbers of these goat-like animals, and at the present time they are still to be found there.

The sheep, llama, and guanaco are very numerous.

The **Guanaco** is the largest of these llama-like animals now found there.

In Fig. 85 we see this animal with his great enemy, the puma.

The guanaco is a larger development of the descendants of the xiphodon under the favoring conditions that prevailed in the Post-Tertiary period.

They are now rapidly undergoing complete extinction, and will soon disappear.

I saw numbers of them in Southern Patagonia, and on the shores of the Straits of Magellan. Being unused to the sight of man they were fearless, and quite docile in their manner, approaching to within a few yards of us, and slowly retreating as we went towards them.

As our steamer sailed through the eastern part of the Straits of Magellan, the guanacos, accompanied by numbers of ostriches, ran along the bank endeavoring to keep pace with us, stopping now and then to gaze curiously at us, and then following on again.

Ostriches in considerable numbers still inhabit the plains of Southern Patagonia. They differ slightly from those found in Africa, in having coarser feathers, but the evolution of both is the same.

They have followed the same line of development as all the other long-legged birds, the *Dinornis* of the

Quaternary period, and the storks, emus, and cassowaries of more recent times.

As we approach the torrid regions bordering on the Amazon River, we find a multitude of forms of life of great variety.

FIG. 85.—PUMA ATTACKING GUANACO.

Here we see great serpents that have descended from the Tertiary period, the most common being the boa.

In Fig. 86 we have a good view of one of these serpents. I have seen them many times in the forests near Para, and farther up the Amazon River. In these same forests, which extend for hundreds of miles, are immense numbers of different forms of animal life.

The shores of the Amazon abound with huge alligators. Now and then a puma comes to the water's edge to slake his thirst. Great numbers of toucans *(Rhamphastidæ)* tenant these great woods, and wage a destructive war upon their neighbors.

FIG. 86.—BOA CONSTRICTOR.

A great variety of **Parrots** are also found there, more than thirty species having been studied. The most common variety found there, and that I have been able to study, is the Amazon parrot *(Chrysotis)*. This bird is found very extensively in the Amazon forests. I have seen them also on the Orinoco River, and in the woods bordering the Rio Magdalena, and on the Isthmus of Panama, where they are found in considerable numbers.

Throughout Brazil are vast numbers of **Humming-Birds** *(Trochilidæ)*. They are extensively distributed throughout the tropical zone. About five hundred varieties have been found. They are all of small size, and of brilliant plumage, with a bright metallic lustre. They find ample food in the riotous insect life of those regions.

The humming-bird of Brazil is the most common variety, and all are variations from a common stock.

Several species of **Monkeys** *(Cebidæ)* are found in South America, and it will be seen later on that they differ widely from the great apes of Asia and Africa, although all of them are descended from a single species. In several localities in Southern Europe, in the upper Mississippi region of our own country, and recently in Northern Brazil, have been found in the Miocene deposits, fossil bones of a dog-like ape. This ape had a long tail, but the rounded form of the terminal caudal vertebræ leads us to believe that it was not prehensile.

This Miocene dog-like ape was, like the dogs and hyenas of that period, descended without doubt from the anoplotherium of the preceding Eocene period. This latter animal, in the course of ages, diverged in structure along closely related paths, and from him the dogs and hyenas were evolved. It needed but a further slight divergence to produce an ape exceedingly dog-like in its anatomical structure.

From this Miocene ape all succeeding varieties are doubtless descended. We have already studied his special evolution and development, of an arm and hand.

The monkeys of South America are of two general kinds, those with long prehensile tails and those with long non-prehensile tails. Among each are several varieties, and most of them are found in the great forests of the Amazon valley. A few have a wider geographical range, and are found from Paraguay to Mexico. The more important of the prehensile-tailed monkeys are the howlers *(Mycetes)*, the spider monkey *(Ateles)*, the Barriguda *(Lagothrix)*, and the Cai *(Cebus)*. In Fig. 87 we see the spider monkey.

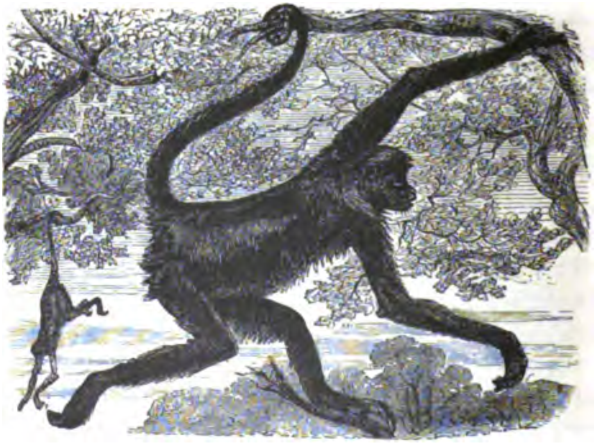


FIG. 87.—SPIDER MONKEY.

All these monkeys have long, sensitive, prehensile tails which serve as a fifth hand, and is well suited to their active arboreal life. The terminal caudal vertebræ are flattened, and very mobile. The muscles are well developed, and supplied with sensitive and motor nerves from the sacral plexus. They are found in great numbers in the Amazon valley. While in the forests above Pará, I saw hundreds of them in the trees about us, the howlers and the spider monkeys being the most numerous. While there, and also in the forests south of Panama, I have subsisted wholly for several days on the flesh of the spider monkey and plantains fried in the animal's fat. The flesh of these monkeys is delicate and palatable, and esteemed by the natives as an article of food.

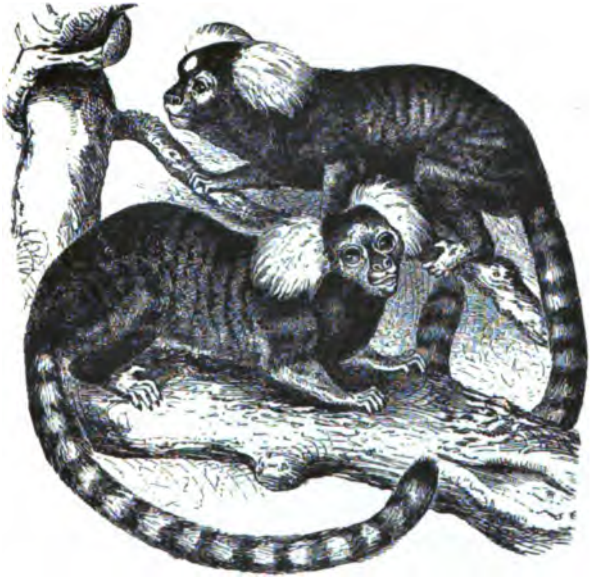


FIG. 88—THE COMMON MARMOSET.

The non-prehensile-tailed monkeys are the marmosets *(Hapale)* and the tamarins *(Midas)*. The others are unimportant. They have long non-prehensile tails, covered with bushy hair. The terminal caudal vertebræ are rounded and have a limited motion. Their digital extremities are furnished with a claw, and their anatomical structure, habits, and modes of life place them nearer to the squirrels than to the apes.

In Fig. 88 we see the common marmosets.

The **Condor** is occasionally seen in the mountain regions on the western border of South America. Here, among the higher altitudes of the Andes, he finds a habitat congenial to him. But as he is purely a scavenger bird, rarely attacking living prey, he descends to the more level country in search of food.

In a somewhat extensive tour in the Andes Mountains I have seen but few of these great birds. Their fossil bones have been found in considerable numbers in the Post-Tertiary deposits, but they were less numerous in Quaternary times, and in modern times they are nearly extinct.

The law of retrogression applies to them and will continue until it ends in their complete extinction.

This bird offers an example of great power to endure extreme changes of heat and cold and of atmospheric pressure.

I have watched these birds on the coast of Guayaquil where they came down to gather dead fish on the shore. The heat was tropical. Having secured their food, they flew to the mountains and rose to an altitude of more than sixteen thousand feet, or very near the perpetual-snow line. The range of temperature could not have been less than 90° F. in a few moments, yet these birds endure this violent change without apparent inconvenience.

In Fig. 89 we have an excellent view of one of these great vultures.

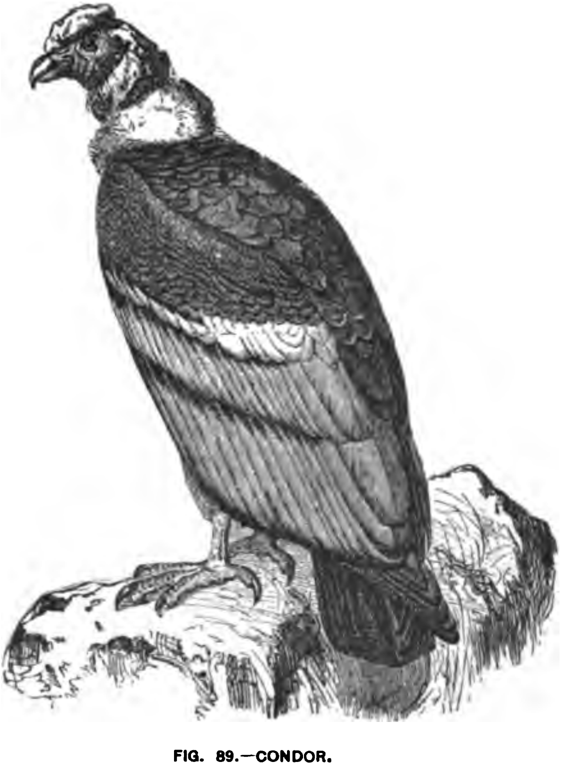


FIG. 89.—CONDOR.

As we reach the more northerly regions of South America, or those lying directly under the equator, we find an exuberance of *insect* life.

In the Tertiary age we find evidences of a few lowly organized insect forms. In the Post-Tertiary age these forms were greatly multiplied, but it was not until the Quaternary age set in that insect life reached its climax of development.

Among the more important of these insects are the *bees*, *wasps*, *ants*, and *beetles*. They are among the higher orders of insect evolution and intelligence.

In the Jurassic deposits remains have been discovered that are believed to belong to **Bees.** These are among the earliest, if not the earliest, forms of insect life that appeared upon the earth.

We can easily understand that such an animal form as a *bee* could have been developed from some previous minute form too minute and transitory to leave behind it any definite trace. But there can be no doubt whatever that bees were a result of the law of evolution and development from some previous minute animal organism of a lower grade.

Taking the Jurassic bee as among the very first of the forms of insect life, he could very well be the progenitor of all the other forms that have since appeared, wasps, hornets, and flies, with all their variety of form, are simply a divergent development of insect life, along lines still quite parallel.

The ants and beetles, while presenting great external differences from the bees, may still be the products of evolution from the same original stock, but showing a wider divergence in their more recent development.

The **Ants** are more widely distributed than any other insect of a like growth and intelligence. These creatures are endowed with remarkable powers of brain intelligence and great muscular activity, as well as fierce and predatory habits. They are to the insect and minute animal world what the lions and tigers are to the greater animal world.

The *foraging ant (Eciton drepanophora)* is a fierce beast. They sally forth in vast columns, moving with remarkable regularity and devouring savagely every living or dead animal that comes in their way. As they are ferocious and fearless, and swarm in countless millions, they are a dread to all they meet.

A view of these animals and their habits as seen in their native forests is very interesting. I have watched these ants many times in Brazil and on the Isthmus of Panama.

As we approach the great tropical regions of South America lying under the burning equatorial sun, we meet with two very interesting animals—namely, the **Tapirs** and the **Peccaries.**

In both these animals we see nearly a direct descent from the tapir-like paleotherium of the Eocene period.

Tapirs are now found in the Amazon valley and are occasionally seen as far north as Guatemala, in Central America. I have seen them in the Amazon forests and on the Orinoco, and in Colombia, but I have seen none north of Costa Rica.

They are also found in India and in the islands of Sumatra and Borneo. Few if any are met with elsewhere.

The great progenitor of the tapirs, the paleotherium, needed to change but little, and to diverge but slightly, to evolve the modern animal. The anatomical structure and physiological functions of both are nearly identical.

The paleotherium has transmitted his qualities, habits, and modes of life almost unchanged through so many ages to his modern successor. The mobile lip, the dentition, the heavy, bony skeleton, and the physiological processes of nutrition and reproduction are essentially the same.

The paleotherium, however, lived originally in North America and later migrated to Europe and Asia, and, so far as is now known, he has lived in no other regions. In his original home he is now extinct, and his successor, the tapir, is found in two localities only, and these most widely separated.

The reason of this wide separation is, however, very plain.

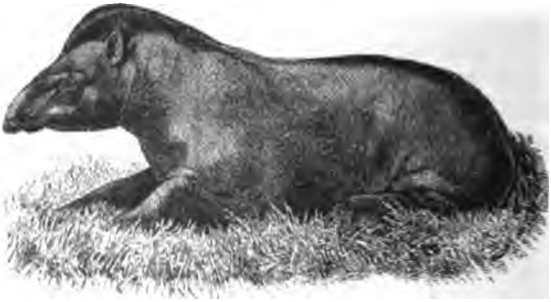


FIG. 90.—AMERICAN TAPIR.

From North America the paleotherium could migrate, during the long ages of the Tertiary and Post-Tertiary periods, to South America along either or both of the highways connecting the two countries. One, the Isthmus of Panama, the other, the great bridge of land, where now exists only the chain of the Windward Islands. By these two routes he could reach the vast and congenial regions of South America that have supported him ever since, and transmitted him almost unchanged to our own time. From North America he could also migrate to Asia, whose boundless steppes gave a congenial home to vast herds of these animals, in the equable climate of the same geological periods. He then found ample time to migrate by easy stages to what is now Southern India, before the great barrier of the Himalaya Mountains lifted its snowy head to intercept his passage. Continuing southward, he was able to reach those great stretches of land that have since become the islands of Java, Sumatra, and Borneo.

Here he has continued through long ages, and finally undergone the slight changes that have transmuted him to a tapir.

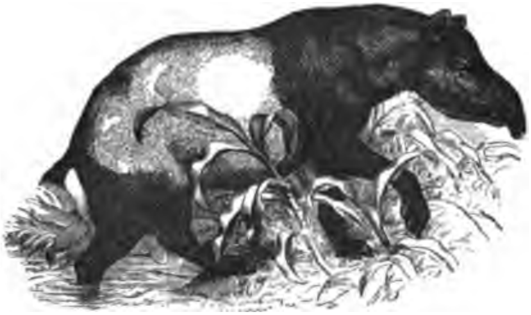


FIG. 91.—ASIATIC TAPIR.

In Fig. 90 we see the American form of tapir as he is found in the Amazon valley to-day, and in Fig. 91 we see the Asiatic tapir as he is found in India, Java, Sumatra, and Borneo.

Both these varieties of tapir can claim a common ancestor in the paleotherium of the Eocene period, and while they are so widely separated in their modern habitat by migration, they have diverged but little during the subsequent ages from their tapir-like progenitor.

They still closely resemble this progenitor in external appearance, while if we compare their osteology with the fossil bones of the paleotherium we shall see a striking similarity.

Their physiological functions, habits, and modes of life must have been identical.

Those pig-like animals, the peccaries, are undoubtedly a degenerate or undeveloped variety of tapir. As they are found in the same localities, and bear a strong resemblance to the tapirs in their habits, modes of life, and osteological structure, but are smaller in stature, this view admits of no reasonable doubt.

Two varieties of peccary are found in Central and South America, the common peccary *(Dicotyles torquatus)* and the white-lipped peccary *(Dicotyles labiatus)*. I have seen great numbers of the former on the Isthmus of Panama, and shot a fine specimen where the Panama Railway passes through the Chagres valley. I have also seen the white-lipped peccary in the forests of the Amazon valley.

The white-lipped peccary is larger and more ferocious than the common peccary, but both are descended from a common stock, and have developed along lines that are but slightly divergent. The **Capybara** *(Hydrocherus capybara)* or water pig is another of the pig-like animals, bearing a close general resemblance to the peccaries. It differs from them in two anatomical points. It has the incisor teeth of the rodent, and the hoofed toes are connected by a firm tegumentous web, which enables him to swim freely.

When seen in the forests of Brazil at a little distance I have been unable to distinguish a peccary from a capybara. It needed a near view to tell one from the other, especially when they both drank at the same time at the water's edge on the Amazon River.

There can be no doubt that the tapirs, the peccaries, and the capybaras have followed closely parallel lines of evolution from a common ancestor—the paleotherium, who was himself a tapir-like animal who lived and flourished in the Eocene period, and who was the progenitor of many modern forms of animal life.

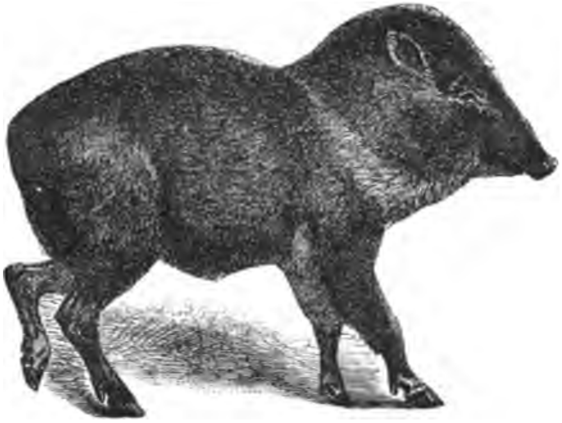


FIG. 92.—PECCARY.

A later development of this same pig-like animal stock is the wild boar *(Sus scrofa).* This formidable beast dwelt for ages in the warmer regions of Asia and Africa, although he first appeared in North America. He belongs to the great order of the pig-like animals.

If we study his dentition as seen in Fig. 93 we shall see that, like the capybara, he has some rodent qualities.

Fossil bones of the boars *(Suidæ)* have been found in Miocene deposits in North America, the original home of this animal, and a study of his special structure leads us to believe that he is descended from the paleotherium. He differs in no essential points from the tapirs, peccaries, and capybaras, and from him have sprung the modern varieties of hog by the processes of domestication and artificial selection.

In that subdivision of the age of reptiles called the Jurassic period, we saw the evolution of a singular creature, partly reptile and partly bat—the pterodactyl. This reptilian bat stood as an intermediate step between the reptiles of that age and the bats of the succeeding age.

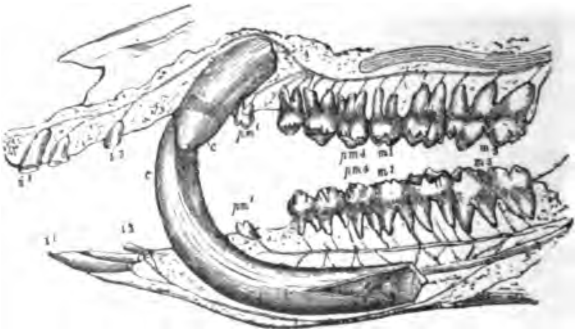


FIG. 93.—DENTITION OF WILD BOAR.

He was not clothed with feathers, nor did he possess a true wing, but he did have a great development of the bones of the fourth finger, which acted as a framework to support an expansion of his integument into a thin, translucent membrane, which served for the purposes of a partial aërial flight.

While he transmitted certain of his functions to other animals, he also transmitted other functions to a succeeding species of animal—the bats. His physiological functions became modified into those of a mammal, but he transmitted his bony, digital framework, his membranous expansion, and his dentition, which subsequently underwent some changes, to the bats.

In the Quaternary age these singular mammals have diverged considerably in respect to their tegumentary development, but their essential anatomical characters are practically the same.

They are all insectivorous mammals, with nearly identical habits and modes of life.

If we study the skeleton of the bat we notice his great development of the bones of the fingers to support his wing membrane.

He is a true mammal, an insectivorous beast, fierce and uncouth, and a dweller in out-of-the-way and uncanny places. Some of them, as the vampire bat, have a rather unsavory reputation, as delighting to suck the blood of innocent sleepers.

As we proceed farther northward we reach the immense area of North America. Here life first dawned upon the earth, here evolution progressed steadily through all the ages, and from here the most important forms of life migrated to other parts of the earth.

In the present age few of the larger forms of animal life are found here. Most of them find a more congenial habitat elsewhere. One of the most important, and formerly the most numerous, of these great animals was the **Bison** *(Bison Americanus)*.

This animal was formerly widely distributed over the greater part of the continent of North America, and existed in vast numbers until within a comparatively recent time. As late as the year 1872 it was seen in immense herds on the great plains that lie west of the Missouri River. I have seen great numbers of the buffalo on the plains of Kansas, Nebraska, Colorado, and Montana. The fossil bones of the bison have not thus far been found at a lower horizon than the late Pliocene period, and hence it is believed that his evolution did not occur earlier than the late Tertiary age.

The conditions of life were very favorable for his rapid development, and at one period he extended over nearly the whole country. Civilization has, however, been very fatal to him, and he is now nearly extinct.

When we see a view of this great animal, as in Fig. 94, we are led at once to inquire from what previous animal form was he descended. From our present knowledge we find reason to infer that brontops robustus of the Miocene period was his progenitor, or that he was evolved from an earlier form along a rather more divergent line. It is, however, reasonable to believe that brontops was his ancestor, as well as the ancestor of the later order of the *Bovidæ*. Brontops was a huge herbivorous mammal living amid favorable conditions of life in our western territories. He could easily undergo the changes necessary to transmute him to newer forms—the *bison*, *bull*, and *musk-ox*, in the long gap of time between the Miocene and Pliocene periods. Such changes were not great nor violent, and relate to size chiefly, and to some points of osseous anatomy.

The fossil bones of the sivatherium have been found in our western country and the Siwalik Hills of India, thus showing how widely he was distributed. The evolution of this animal from the xiphodon of the Eocene age, which scarcely admits of a doubt, was a change no greater than the change from brontops to a bison. We may at present, at least, accept this view. In the divergence of the xiphodon to give rise to the sivatherium, he also gave rise to many varieties of the deer-like animals, as the yak, anoa, giraffe, and prong-horn antelope. There is a very close similarity between this group of animals, as there is between brontops and his successors—all are herbivorous in their habits, and all except brontops have a regular well-formed two-toed hoof, the other three digits being either rudimentary, consolidated, or existing as partially developed toes or dew-claws.

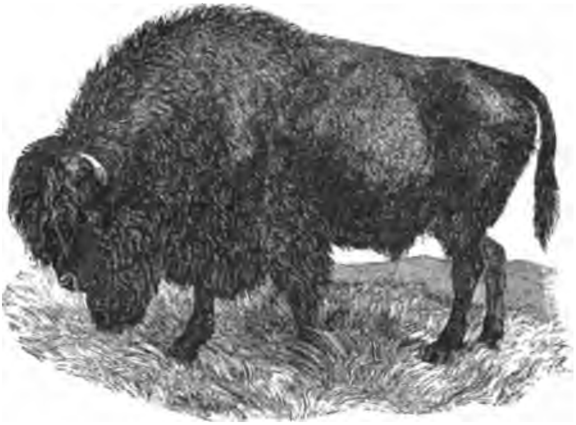


FIG. 94.—AMERICAN BISON.

They are also ruminants ; the physiological process of remastication of the food belongs to all. Their dentition is also nearly alike. The molars are fitted for triturating vegetable substances, and the anterior portions of the jaws, the pre-maxillæ, are fitted for grazing.

The process of *rumination* was a function that undoubtedly arose after the evolution of the great carnivora of the Post-Tertiary period, and bears some relation to the instinct of self-preservation and safety.

The paleotherium, the anoplotherium, and the xiphodon were herbivorous animals, but they were not ruminants. Being without destructive enemies they could feed at will, and digest their food at leisure in a simple stomach. But their successors, following out on lines of slightly varying evolution in a later age, when great carnivorous beasts abounded, were compelled to adopt some means of safety. As they were without weapons of defence, they could seek safety only in flight. As the great carnivora preyed eagerly upon them, they found themselves greatly harassed by such ferocious enemies.

They were obliged, then, to graze rapidly, and, however abundant the vegetation, they were compelled to feed upon it hurriedly and flee away for their lives to a place of safety. This mode of life was followed by inevitable physiological consequences. The vegetable food thus rapidly swallowed and imperfectly masticated, was not received into the stomach in a fit condition to be digested and assimilated. Accordingly, when the animal had fled to a place of safety, with his stomach full of coarsely masticated food, his physiological needs led to the development of a new and special function—that of regurgitating his food in successive portions back into his mouth, there to undergo a further and more complete process of mastication, to fit it for ultimate digestion. This regurgitative act necessarily induced anatomical changes in the stomach itself. This organ, which was a simple muscular sac in the animals of the preceding ages, now began to dilate its walls under the stimulus of its new functions and new uses. Lateral muscular pouches formed to receive the re-masticated morsels and convey them thence to the pylorus, to be absorbed into the circulation by the intestinal villi just beyond.

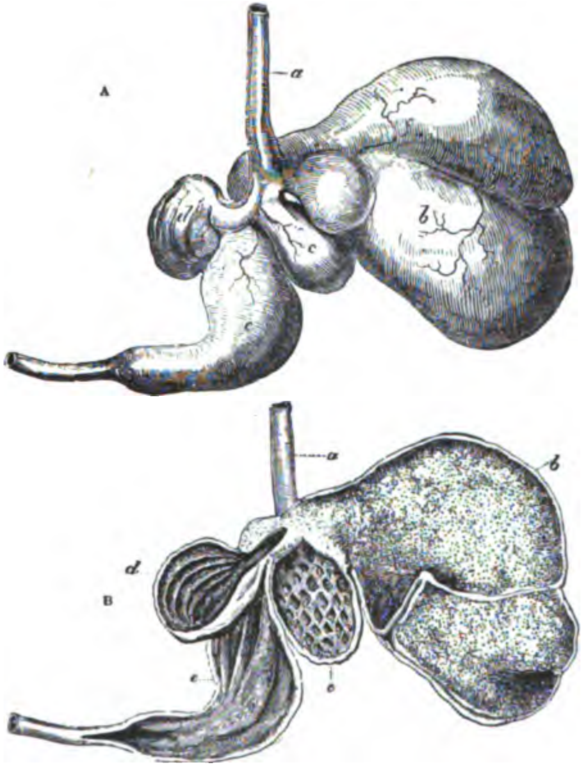


FIG. 95.—STOMACH OF A RUMINANT.

Such a process—of regurgitation and re-mastication—finally led to the development of a stomach with one or more lateral pouches fitted to accomplish this complicated and special work, and as a result we have the stomach of a *ruminant*, as seen in Fig. 95.

In the lower cut showing the interior of the stomach we see the esophagus *a*, which conveys the food to the pouch *b*. From here the coarsely masticated food is sent to the second stomach *c*, which has, in modern animals, an inner mucous membrane arranged in shallow hexagonal cells. This organ, by a powerful muscular contraction, forces the morsel of food back into the mouth, where it is masticated finely and duly mixed with the secretions of the salivary glands. After this it is again swallowed and passes into the third stomach or pouch *d*. From this organ it is sent to the fourth stomach *e*, where it meets with the gastric juice, and undergoes a nearly complete digestion. It then passes the pylorus and enters the small intestine, where digestion is completed, and where the nutritive portions are absorbed by the intestinal villi, and conveyed to the general circulation of the blood, and then appropriated by the various tissues of the body in the processes of nutrition and growth.

The **Musk-Ox** *(Ovibos moschatus)* is an animal resembling the bison in its general anatomical configuration, and is doubtless descended from the same ancestor, following a rather more divergent line of evolution.

It finds a congenial habitat in the most northerly parts of America, but its final extinction is not far distant.

Its external characters are determined by its mode of life in a cold climate. Its osteology differs but little from that of the bison. In both animals the fundamental characters of structure are the same.

The **Prong-Horn Antelope** *(Antilocapra Americana)*, the **Elk** or **Moose Deer** *(Alces machlis)*, and several smaller varieties of deer *(Cervidæ)*, are found in North America.

They can all claim the same ancestor, the xiphodon, and each has followed his own special line of evolution and development.

The prong-horn antelope, which is found so extensively in the northwestern part of our country, and also in the Rocky Mountain region, differs in one important respect from the deer proper. In the latter (the *Cervidæ*), the horns are composed of *solid* bone, and are shed and reproduced each year, growing from the soft vascular integument of the head called the *velvet*. In the prong-horn antelope the horn is *hollow*, and grows upon a horn-core. This is permanently attached to the skull, and upon it the outer bony pronged horn of the animal grows, and is shed each year.

In this animal we see an intermediate step between the solid bone, annual horn of the deer, and the permanent tegumental horn of the ox growing upon a bony horn-core.

In North America there is a group of animals which are classed under the term **Cynoidea**, or dog-like animals. These include the wolves, foxes, jackals, and dogs. We have seen that in the Eocene period the anoplotherium lived and flourished in vast numbers, and over a great area of Asia and North America. In the course of ages he diverged and gave rise to other animal forms, and among these were two animals closely resembling each other, namely, the dogs and hyenas, which appeared in the Miocene period.

The anoplotherium needed to diverge but little to permit the evolution of these two animals from him. The greatest differences were in the formation of the claw, and the growth of the prehensor or canine teeth. The habits and modes of life of the dogs and hyenas were such as to induce anatomical changes in both tooth and claw. They were both scavengers, as we have already seen, and lived upon the flesh of dead animals. In order to feed upon these, a sharp tooth was necessary to tear the resistant tissues, and a blunted claw was needed to dig and scratch the ground to conceal their food from other animals.

FIG. 96.—WOLF.

These anatomical characters have been transmitted from the Miocene period to the present time, and we have in the wolves, foxes, jackals, and dogs of modern times the same arrangement of anatomical structure that characterized the earlier species. We can say that the anoplotherium was the progenitor of the whole group of the *Cynoidea*.

The differences between these four groups of animals in a *feral* state are very small. All are dog-like in their structure, functions, habits, and modes of life. The differences between them are exceedingly superficial, and are chiefly those of size and color, due to climate and local habitat.

If we compare the wolf *(Canis lupus)* with the jackal *(Canis aureus)*, the fox *(Canis vulpes)*, and the dog *(Canis familiaris)*, we shall see they belong to the same species, and that all sprung from a common ancestor, the anoplotherium. Their evolution from him during the long subsequent ages has been along remarkably parallel lines of special development and a growth of very similar characters. The varieties of domestic dog are solely the result of special selection and breeding. The varieties of wolves, jackals, and foxes are due to the influences of local habitat. The common gray wolf and the coyote found on our western plains and in the great forests of the northwest, differ but little from each other.

FIG. 97.—JACKAL.

In crossing from the Ozark Mountains in Southwest Missouri through the Indian Territory and the plains of Kansas to Denver, our party was terribly harassed by hordes of gray wolves. Several hundred of them followed us day and night, and we, six in number, with our horses, barely escaped with our lives. At night our camp-fires of "buffalo chips" kept them at bay, but their angry red eyes glared close to us in the firelight. They left us only upon our reaching the arid region on the borders of Colorado.

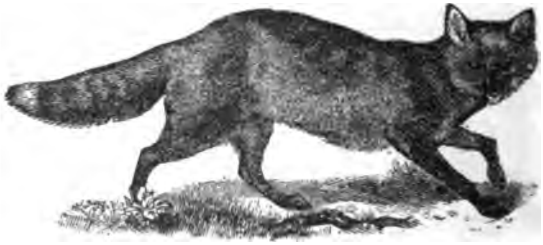


FIG. 98.—COMMON FOX.

This species of wolf was formerly extensively distributed throughout North America, and is still found in the great forests of Northern Russia, where it is a dangerous beast to travellers, rarely failing to attack man whenever they meet him in his journeyings in that inhospitable region.

The group of the **Arctoidea**, or bears, has several typical representatives in North America.

The dogs and hyenas were, as we have seen, the first of the carnivorous animals that were evolved from their common ancestor, the anoplotherium. Closely following them were the bears. These three animals, the dogs, hyenas, and bears, were the first to depart from their original progenitor, and to follow diverging lines of their own special evolution and development.

None of them, however, are *true carnivora.* They still retain some of the original herbivorous habits of their ancestor, and form a grade of evolution from an animal wholly herbivorous to those only partly so. The group of bears belong to the plantigrades, or those treading firmly upon the plantar surface, or sole, of the foot.

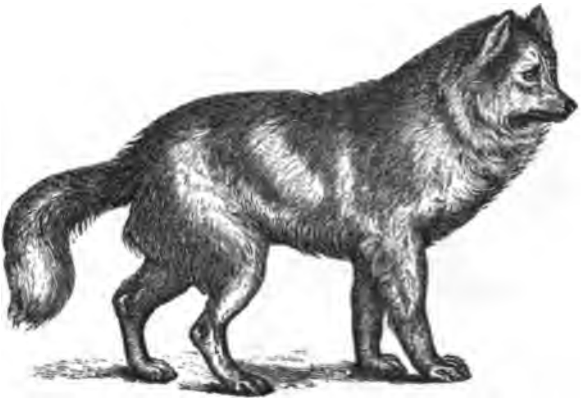


FIG. 99.—INDIAN DOG.

Their anatomical structure is essentially the same, and all have followed the same line of evolution and development.

The **Polar Bear** is a fair type of the North American arctoids. He is, however, more thoroughly carnivorous in his habits than most of his class, but this is due solely to the influence of habitat. Living as he does in the icy regions of the far north, he depends wholly upon the flesh of seals and walruses for his food. But he would subsist, as other bears do, upon a mixed diet if he lived in a warmer climate.

The polar bear *(Ursus maritimus)*, the grizzly bear *(Ursus ferox)*, the black bear *(Ursus Americanus)*, and the brown bear *(Ursus arctos)* of North America, the sloth bear *(Ursus labiatus)* of India, the Tibetan sun bear *(Ursus Tibetanus)*, and the Malayan bear *(Ursus Malayanus)* of Southern Asia are all a product of evolution from one and the same original stock, the anoplotherium of the Eocene period.

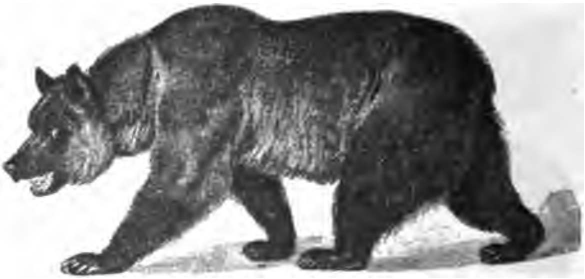


FIG. 100.—GRIZZLY BEAR OF NORTH AMERICA.

When compared with the great bears of the Post-Tertiary period, we see that they have undergone a perceptible degeneration in size. Even the great polar bear and the dreaded grizzly bear of the Rocky Mountains cannot compare with the earlier species. All animal life from the Post-Tertiary period, when the earth teemed with so many and such great forms, has slowly and steadily diminished. The larger forms are perceptibly declining, and we now see a much greater number of the *smaller* animals than of the *larger*.

One of the most extensive groups of the lesser animal forms is the *rodents*, or those animals having a special form of dentition that fits them to gnaw woody substances. One of the most highly developed of this group is the **Beaver** *(Castor fiber).* This animal has a wide distribution over the whole of North America.

It is the largest of any of the rodentia, being about thirty inches in length. It is one of the few of the rodents that is *aquatic* in its habits. This mode of life has led to a special development of a web, or tegumentary expansion between the digits of the posterior extremities, to enable it to swim in the water. As it dives beneath the surface of the water frequently to construct and reach its nest, it has greatly developed the lateral caudal muscles to enable it to meet this special need, and the tail is in consequence broad and flat, and acts as a posterior oar.

The **Musk-Rat** *(Fiber zibethecus)* is a smaller rodent of similar aquatic habits.

The **Prairie-Dog** *(Cynomys ludovicianus)*, the **Striped Gopher** *(Spermophilus tridecemlinatus)*, and the **Common Hare** represent a very extensive class of the rodent animals, all of small size and wide distribution.

The **Squirrel** *(Sciurus vulgaris)*, the **Rat** *(Mus rattus)*, and the **Mouse** *(Mus sylvaticus)* also represent a large class of the smaller rodentia.

The entire series of the rodents are strikingly alike in their special dentition, anatomical structure, physiological functions, habits, and modes of life. Their differences are chiefly those of size and external superficial appearance. They may be regarded as a lesser development in point of size, and a degenerate evolution along very slightly diverging lines from some preceding form. This form can well be some animal who has entered upon a retrograde path of evolution, and who was himself descended from the paleotherium.

If we will review the long line of these special animal organisms, from the tapir to the peccary, capybara, agouti, paca, cavy, beaver, prairie-dog, hare, rabbit, gopher, squirrel, rat, and mouse, we shall see a striking similarity of anatomical structure, an *identity* of physiological function, and between many of them habits and modes of life alike.

At first sight the gap seems wide between a tapir and a mouse, but in order to compare them it must be remembered that size is only relative. Raise the mouse to the size of the tapir, or diminish the tapir to the size of a mouse, and compare their osteology, and the differences are extremely slight. They consist chiefly in the differences of dentition. The external appearances, even, are much less than would at first appear. The tapir, as we have seen, was descended along the same lines as the megatherium—an edentate,—and he still retains the mobile lip and imperfectly developed incisor teeth of his ancestor. His toes are hoofed to protect them from injury. The mouse has a short but extremely mobile lip also, and small incisor teeth fitted for the function of gnawing.

If the mouse could attain the size of a tapir, he would soon lose his rodent incisors by the operation of the law of disuse, and his lip under the other law of use would soon grow longer and more mobile, and more tapir-like. His feet, which are now furnished with a non-retractile claw, would grow heavier and stronger to support the weight of his body, until finally a hoofed foot would be formed as in the tapir.

And conversely, if the tapir could diminish himself to the size of a mouse, he would, under the operation of the law of use and disuse, lose his prehensile lip and his hoofed foot, and develop an incisor tooth and a non-retractile claw.

In all these animals the physiological functions of nutrition, reproduction, and growth are the same.

If we study the whole series of animals now under consideration, from the tapir to the mouse, we shall see it is a gradation from a large animal to a small one, but through them all there is a uniformity of anatomical plan in most of the essential principles of the structural organisms.

We have no difficulty in tracing back to a common ancestor all this long and numerous line of special animal organisms. That ancestor, as has been already stated, is one of the forms, without doubt, that developed along the same lines as the megatherium—that great South American edentate of the Post-Tertiary period, who himself can claim the paleotherium as his progenitor. The descent from one animal of so many lesser forms has been accomplished through long lapses of time by the process of evolution along closely parallel lines of development and growth, influenced by climate, habitat, habits, and modes of life.

These influences are very powerful when they act through the long flight of ages, and especially when they are strongly aided by the law of natural growth and natural selection.

All the birds and insects of North America have followed the same path of evolution, of variation, and growth.

CHAPTER XIV.

POST-TERTIARY PERIOD:—THE AGE OF MODERN FORMS OF LIFE—CONTINUED.

The Quaternary period—The Æluroidea or cat-like animals—The Felidæ: lion, tiger, leopard, and the whole order of cats—Civets—Genette—Ichneumon—Paradoxure—Binturong—Aard-wolf—Giraffe—Camel—True camel—Bactrian camel—The Bovidæ: sheep, goat, ibex, saïga, Indian antelope, eland, koodoo, gnu, gemsboc, chamois, oryx, nylghau—Fallow-deer—Sambur deer—Rusine deer—Muntjac—Chinese water deer—Roebuck—The Chinese elaphure—Reindeer—Observations on birds, fishes, and the multitude of animal forms—Condition of the earth—It favors development of animal life—Elephant—Hippopotamus—Rhinoceros—Insect life—Infusorial life—The brain—Cerebellum—Olfactory bulbs—Gray matter.

IN passing from the immense continent of North America to the vast and fertile regions of Africa and Asia we find a profusion of animal forms unknown to any other parts of the earth. Many of these forms are of large size, and have reached an advanced grade of special anatomical development. At the head of these special forms stands the great order of the **Æluroidea** or *cat-like* animals. These are strictly carnivorous and predatory in their habits, and, under the stimulus of this mode of life, have developed special organs to enable them to seize and hold living prey, and to devour and digest it. These special organs are the sharp retractile claw, the long, slightly recurved, prehensile canine tooth, and the simple sac-like stomach, with a short intestinal tract. As they subsist wholly upon living animals, which they are compelled to pursue, capture, and kill, they have developed a nature that is cruel, eager, and intensely ferocious. This ferocity is so great as to render them highly dangerous and exceedingly destructive to most other animals. They find by preference a congenial habitat in the warmer regions of Africa and Asia, and rarely venture into colder latitudes. The more specialized members of this great group are called the *Felidæ* or those belonging to the genus *Felis* or *cats*.

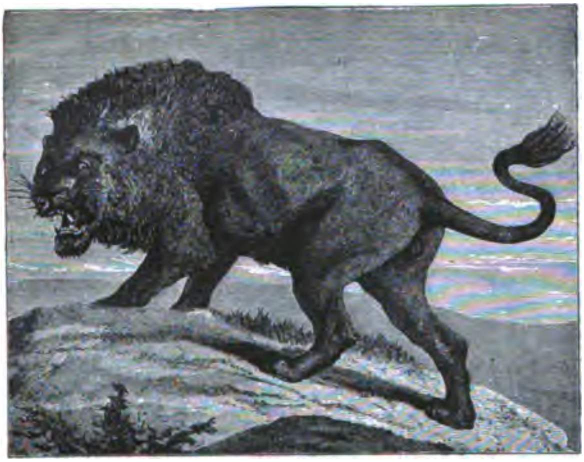


FIG. 101.—LION OF AFRICA.

At the head of the *Felidæ* stands, by common consent, the great cat called the **Lion** *(Felis leo)*. This great carnivor with his special anatomical development is well shown in Fig. 101.

Equally important with the lion, and in some points of a more highly specialized development, is the **Tiger** *(Felis tigris)*. The climax of ferocity and destructive tendencies is reached in this special organism.

His fine color and hair markings are due to the influences of climate and local habitat.

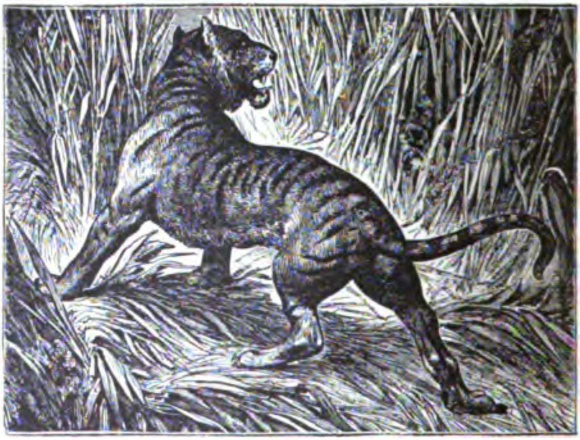


FIG. 102.—TIGER OF ASIA.

Besides the lion and the tiger, the more important members of the *Æluroidea*, are the great cat-like animals known as the

leopard,	*Felis pardus.*
ounce,	*Felis uncia.*
clouded tiger,	*Felis macrocelis.*
ocelot,	*Felis pardalis.*
serval,	*Felis serval.*

lynx,	*Felis lynx.*
cheetah,	*Felis jubata.*
leopard cat,	*Felis Bengalensis.*
bay cat,	*Felis aurata.*
spotted wild cat,	*Felis torquata.*
common wild cat,	*Felis catus.*
Egyptian cat,	*Felis maniculata.*
domestic cat,	*Felis domestica.*

All these animals are found in Asia and Africa, and none of them, except the domestic cat and lynx, are seen in America. Their present habitat is in the warmer zones of the earth, and has been since the close of the Glacial period.

All this group of the *Felidæ*, from the lion of the jungle, to the cat that purrs at our firesides, belong to the same special order of anatomical organisms. The anatomy of all is alike, as is also the physiological functions of nutrition, reproduction, and growth. The habits and modes of life are the same.

We have seen that the lions and tigers of the Post-Tertiary period attained a great size in point of development and anatomical growth. The earth was then a rich and universal pasture from the equator to the poles, basking under a perpetual summer sun, and affording a congenial habitat to vast herds of huge herbivorous mammals, who found the conditions of life easy.

Under such favorable conditions of agreeable climate, abundant food, and consequent ample nutrition, these beasts multiplied greatly, and developed to a great size, and became exceedingly destructive to the peaceful herbivors of that age.

The immense development of herbivorous life stimulated the evolution of the great *carnivors*, and the fossil bones of the special animals of that age tell us that they grew to a size unknown to us.

In the Quaternary age these carnivorous beasts show a retrogression in point of size, and are developing along degenerate lines, until under the influence of the law of destructive agencies, and harder conditions of life they will finally reach extinction. The reasons for this inevitable and ultimate extinction are the rapid encroachments that human civilization is everywhere making upon them. They are compelled to retire before the sharp edge of this higher civilization, which so closely and remorselessly presses upon them at every point. As they are themselves destructive in their nature, and of no use to man, being totally incapable of domestication or even of taming, they are destroyed as dangerous and useless enemies.

Their evolution and development was from the carnivors of the Post-Tertiary period, after the Glacial period had receded to its present limits, along closely parallel but diminishing lines. The smaller cats of the Quaternary age are a later and more degenerate evolution from the larger Post-Tertiary species. This degenerate evolution relates to size, the special anatomical structure remaining the same.

The **Viverridæ** or **Civets** are an interesting group of smaller animal forms, and are an intermediate grade between the cats, and the dogs and hyenas. All are carnivorous. The cats have a sharp retractile claw, and sharply pointed canine teeth. The dogs and hyenas have the same sharply pointed teeth, but a non-retractile claw. The civets have the sharp canine teeth, and a claw that is only *half-retractile*, and hence have anatomical points that are intermediate, but common to both.

In Fig. 103 we see the African civet, which differs but little from the Asiatic and lesser civet.

The **Genette** *(Genetta vulgaris)*, the **Ichneumon** *(Herpestes griseus)*, the **Paradoxure** *(Paradoxurus musang)*, and the **Binturong** *(Arctictis binturong)* belong to the same viverrine group.

This last animal is a civet, but it has a long flexible prehensile tail, like the Brazilian monkeys, and is an intermediate step between the *cats* and the *monkeys*.

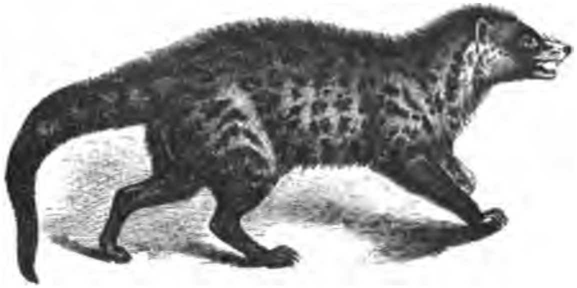


FIG. 103.-- CIVET OF AFRICA.

In Fig. 104 we see the binturong, and we observe certain anatomical characters that belong to the dogs, the cats, and the prehensile-tailed apes.

A close study of these great specialized groups of the dogs and hyenas, the bears, the cats, the civets, and another curious creature, the **Aard Wolf** *(Proteles lalandii)*, will show us that while they have external differences, relating to size, color, hair, growth, and markings, and differences of habits and modes of life, and of mental disposition, there is still a fundamental sameness of anatomical structure and plan. All follow a remarkable identity of osteological development, and all have the same physiological functions of reproduction, nutrition, and growth.

There seems to be no doubt that all these groups of carnivorous animals now under consideration can be clearly traced back to a common ancestor, the Eocene anoplotherium, and that each group has followed out during the succeeding ages his own special line of evolution. These lines of evolution have run in a direction that is very remarkable for its close parallelism of special development. Viewed in the light of scientific comparative anatomy, we see an extraordinary sameness among these groups of carnivorous animals. The entire group of cats, of dogs, of hyenas, and of

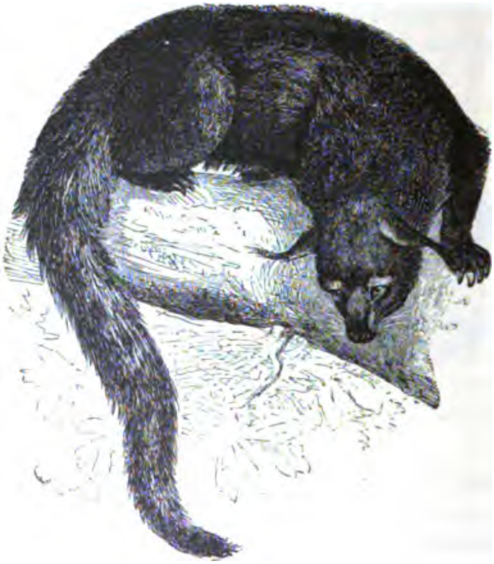


FIG. 104.—BINTURONG.

bears, from the largest to the smallest, can all spring from a common ancestor, and in the course of time undergo the slight changes and modifications of structure necessary to produce the varieties we now see. Many of these varieties were doubtless evolved in the latter part of the Post-Tertiary period, when all the conditions of life were so easy and so favorable, when animal organisms diverged so readily under slight but favoring causes. As these diverging forms multiplied in number, they met in a later age a greater number of destructive influences that tended to check further divergence and evolution, and to diminish their anatomical growth. These destructive agencies are still in active operation, and will go on until all animals not useful to man will be totally exterminated.

Modern civilization is extremely fatal to animal life, and especially to those forms of life that cannot be utilized in this practical age. As this civilization penetrates more and more deeply into the regions of the earth hitherto unexplored by man, evolution of any new forms of life will be impossible, but those forms now existing will be destroyed, as organisms incompatible with the comfort, safety, and needs of man.

The xiphodon of the Eocene period was the common ancestor for a group of animals in the Quaternary age, comprising the sheep, goat, llama, guanaco, camel, deer, and giraffe. When the cold of the Glacial epoch set in, and the great arctic regions became an icy barrier between the vast continental areas lying on either side, the members of this group of animals were divided; some found themselves driven to the American side of this barrier, others were driven to the Asiatic side, where they have since remained. Among the last were the camels and giraffes.

These great animals are clearly descendants of the graceful xiphodon, who has transmitted through the subsequent ages his special anatomical length of neck and limb, until, under the influences of local habitat and special selection and development, they have reached the point of growth now seen.

Both are instances of anatomical development and growth under favorable conditions of life.

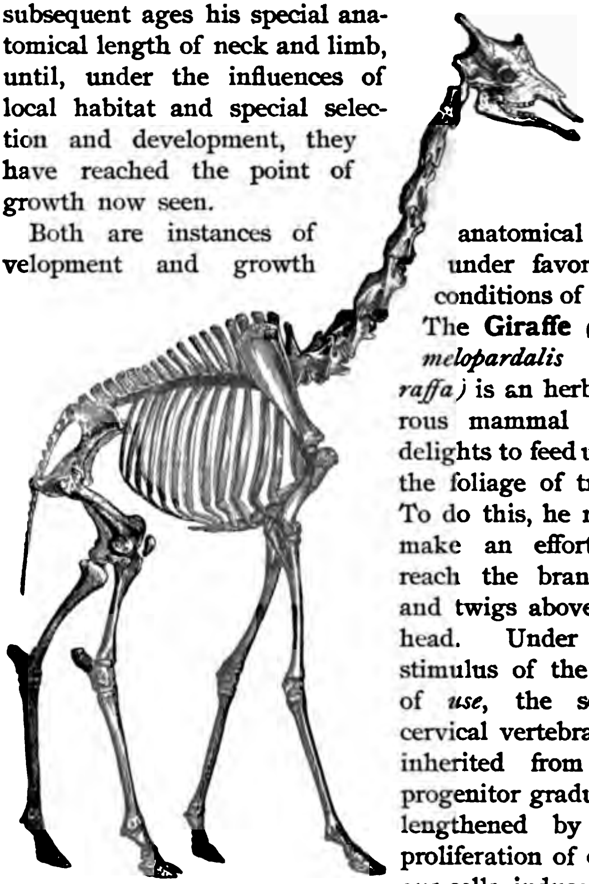


FIG. 105.—SKELETON OF GIRAFFE.

The **Giraffe** *(Camelopardalis giraffa)* is an herbivorous mammal who delights to feed upon the foliage of trees. To do this, he must make an effort to reach the branches and twigs above his head. Under the stimulus of the law of *use*, the seven cervical vertebræ he inherited from his progenitor gradually lengthened by the proliferation of osseous cells, induced by the process of nutrition and tissue growth. By this growth of bony tissue in a longitudinal direction, the neck of the giraffe reached its great length.

The development of his long, flexible, prehensile tongue was stimulated by his special need to bring within reach of his mouth the food he sought, and this need induced a greater nutrition and growth of his glossal tissues. In Fig. 105 we see the skeleton of the giraffe.

A glance at the osteology of this animal will show us that the features which particularly distinguish him are the great length of his cervical vertebræ, and of his metatarsal and metacarpal bones.

These give him a great length of neck and limb. In order to support the weight of this unusually long neck, and to enable him to carry it erect without fatigue, his dorsal spinous processes have undergone an hypertrophy or increased growth, under the law of use and of special need, and these bony spines have enlarged by bony cell-growth to give attachment to a strong nuchal ligament.

We have already seen this special anatomical provision to support the heavy head of other animals.

The **Camel** is also a descendant, along a line of diverging evolution, from the xiphodon of the Eocene period. His path of divergence has been very close to that of the giraffe, and has been induced by similar circumstances. The true camel *(Camelus dromedarius)* is a large organism, with a long neck, long legs, and a powerful osseous structure. The length of the neck is due to the elongated growth of the seven cervical vertebræ, and the great length of limb is due to the special growth of the metatarsal and metacarpal bones, as in the giraffe. As the camel seeks by preference the hot and sandy regions of Africa and Asia, this choice of habitat has led to a special divergence in the anatomy of several important organs. To protect the sensitive eye from the rays of the burning sun, the supraorbital rigde has, as we have seen, by a special proliferation of bone-cells, increased in size until it has formed a bony shelf or projection which screens the eye from the intense sunlight.

The foot, which was formerly a hoofed, two-toed organ, has changed in structure under the influence of a life on sandy plains. The soft and yielding sand has caused an absorption of the posterior part of the horny hoof, and this has been ultimately replaced by an elastic broad muscular pad, fitted better to walk upon shifting sand. This change is not so great as would seem at first sight. The original foot of the progenitor was a hoof covering two narrow toes. As this foot pressed continually upon soft, hot sand, the posterior part, or heel, which was already partly muscular, became more and more so until the horny hoof was absorbed and the muscular pad or cushion was formed over all but the extreme point or toe, and this retained a rudiment of the former hoof in the shape of a protecting nail.

The single hump on the back of the true camel is a fatty growth induced by generous and ample nutrition. Its hypertrophy or atrophy is easily influenced by the nutritive condition of the animal.

In Fig. 106 we see the true camel.

Another variety of this special animal form is the **Bactrian Camel** *(Camelus bactrianus).* This camel has two fatty humps upon his back or dorsal region. Owing to the fact that he migrates farther to the north than his one-humped ally, his hair grows more abundantly, and his bones assume a heavier development.

There can be no reasonable doubt that the camels were evolved from the xiphodon. This creature had a wide range over a great part of North America and Asia during the ages of the Eocene epoch. He seems to have been a transition organism, and gave rise, through slight influences, to many later animal forms.

The camels were among these forms.

A considerable lapse of time was necessary for even the slight changes to be accomplished to transmute a xiphodon to a camel. The ages from the Eocene to the Miocene periods were, however, sufficient to effect these changes. During this long interval the xiphodon slowly changed, under the influences of migration, of change of habitat, and mode of life and natural selection, and eventually an animal form emerged bearing close resemblances to his progenitor, but also showing

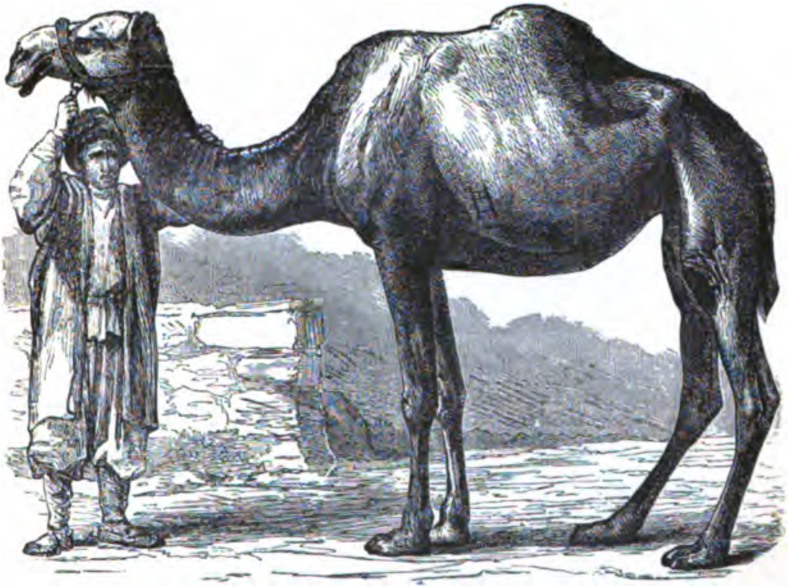


FIG. 106.—THE TRUE CAMEL.

some differences in external form—those parts that change most easily,—and as a result we have the camel. During the Miocene period camels attained to nearly their highest point of development, and reached it completely in the Pliocene. In this age they were very extensively distributed throughout North America and Asia, where their fossil bones have been found in abundance. In the late Post-Tertiary period they became extinct in North America, and continued to survive only in restricted parts of Asia and Africa, where they are now found.

We find two extensive groups of animals in Asia and Africa that found a favorable and congenial habitat in these localities for their evolution, development, and diverging growth. First are the *Bovidæ*—comprising the

Sheep,
Goats,
Gnus,
Gazelles.

Second, the *Cervidæ*—comprising the

Deers.

The *Bovidæ* are the most numerous and the most important, for from them have descended, either by natural selection or artificial breeding, most of the domestic animals that are useful to man.

Some of them are found in both North and South America, but the greater number of them have arisen as a result of a special evolution along slightly diverging paths, exclusively in Asia and Africa.

The most interesting members of the *Bovidæ* are the

Sheep	*Ovis montana.*
Goat	*Capra ægagmus.*
Ibex	*Capra ibex.*
Saïga	*Saïga tartarica.*

Indian antelope	*Antilope bezoartica.*
Eland	*Oreas canna.*
Koodoo	*Strepsiceros kudu.*
Gnu	*Antilope gnu.*
Gemsboc	*Antilope oryx.*
Chamois	*Rupricapra tragus.*
Oryx	*Oryx leucoryx.*
Nyl-Ghau	*Portax picta.*

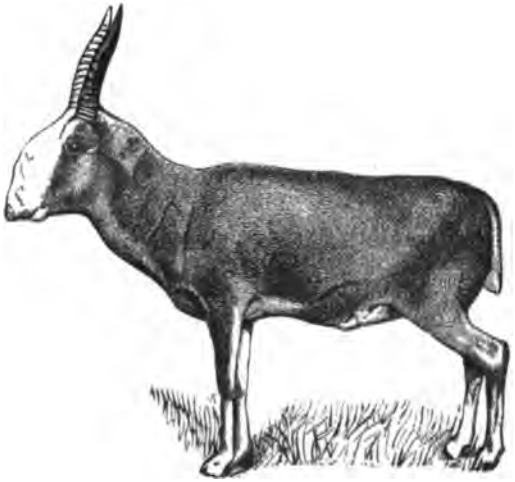


FIG. 107.—THE SAÏGA.

There are several other forms, but of lesser importance in the animal kingdom.

The **Ibex** or **Paseng** is one of the most interesting of this group of animals. It is goat-like in its configuration, and from it have descended all the varieties of the modern goat. The higher lands adjacent to the Himalaya range have afforded a congenial habitat for the evolution of this graceful and interesting creature from his remote progenitor.

The **Saïga** is another variety of those goat-like creatures, and in him we see a slight approach to the gazelles and antelopes, as well as to the sheep.

The **Indian Antelope** rises a little higher in the scale of evolution, and is a more specialized form and a more elaborate development.

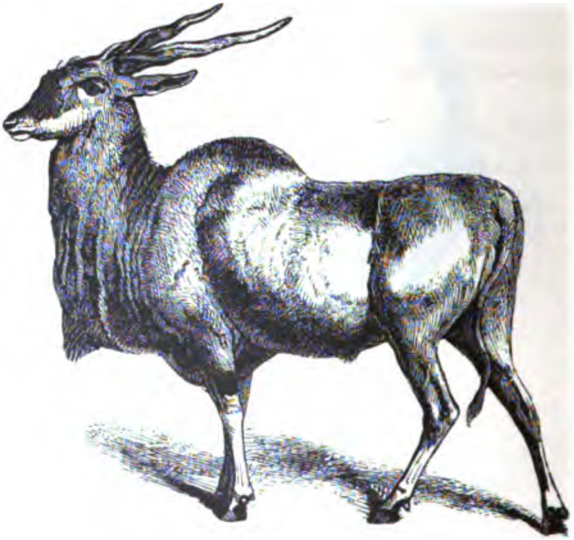


FIG. 108.—THE ELAND.

The **Eland** also presents some of the goat-like characteristics of his fellows, but in him we discern some special traits that point clearly to the ox and closely resemble him.

The **Gnu** is one of the most interesting of the whole group. In this animal we see an organism that partakes of the goat, gazelle, and horse, and in his evolution and growth we find it easy to understand how one animal form can diverge and in the course of time give rise to new forms.

The gnu is very horse-like in his external form, but retains characters that belong also to the goat and gazelle.

In the **Oryx** we find another of those animal forms that by a slight divergence of evolution could change to a deer or an ox.

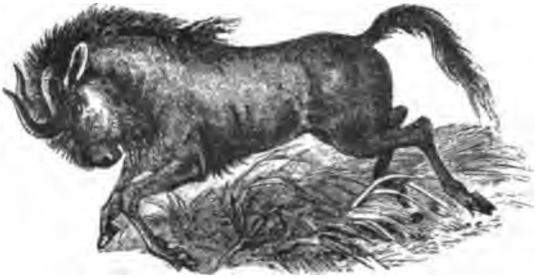


FIG. 109.—THE GNU.

The **Anoa** is an animal that has diverged from its original progenitor, and forms an intermediate link between it and the deer and ox, and closely resembles the South African buffalo.

By a comparison and study of these special members of the *Bovidæ*, we shall see that they are all closely related in form, anatomical structure, habits, and modes of life. Their divergence of evolution and development from a common ancestor has been along lines that were remarkably parallel.

That ancestor was without doubt the xiphodon of the Eocene period.

They are hollow-horned ruminants, the horn being a development of the tegumentary tissues upon a central bony horn-core, and are permanently attached to the head during the life of the animal.

The second group of these animals are the *Cervidæ*, or antlered ruminants, comprising the various members of the deer family. We have already studied the evolution and development of the bony, branched antler which characterizes these animals. It now remains to notice and compare the more important members of this group. It seems probable that their original habitat was the warmer zones of Asia, and that in the course of ages they migrated to Africa and to the cooler regions farther north, where they underwent some changes of external configuration and growth.

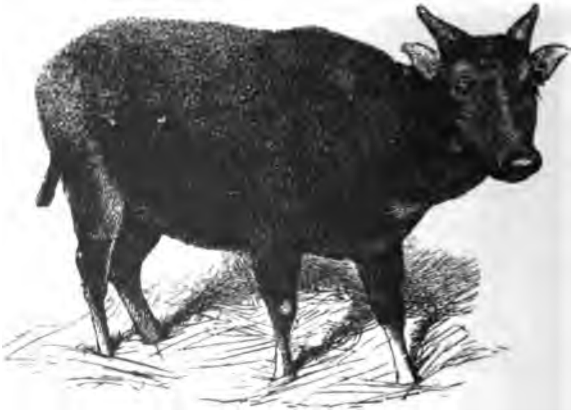


FIG. 110.—THE ANOA.

The **Fallow-Deer** *(Dama vulgaris)* is an important member of this group, and is a slender and delicately developed animal. In modern times it has been partially domesticated by man. It has departed from its progenitor along a slightly varying line of evolution in the development of a somewhat complicated antler and its intricate hair markings.

The **Sambur Deer** *(Rusa aristotelis)* is a more powerfully developed animal than the fallow-deer. Its antlers are large and terminate in three points. The color is dark and the habits and mode of life nearly nocturnal.

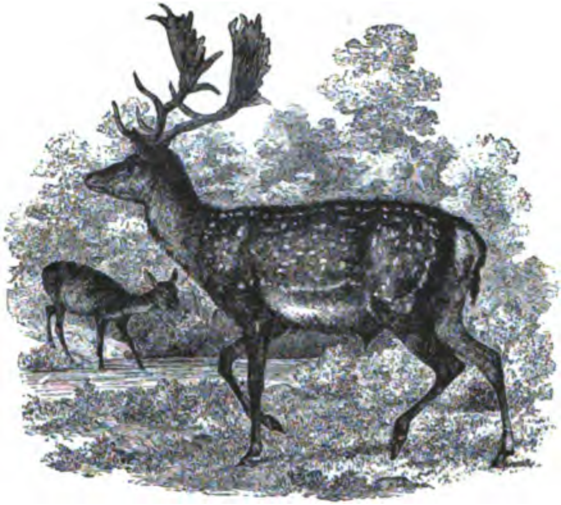


FIG. 111.—THE FALLOW DEER.

The **Rusine Deer** *(Rusa vulgaris)* closely resembles the others in general appearance, but has a more simple development of antler. The contour of the head is like that of the *Bovidæ*.

The **Muntjac** *(Cervulus vaginalis)* is a smaller member of this group. He has a simple, nearly straight, antler, with a small, bony tyne. The antler is developed from a long, bony pedestal attached to the skull, and has a thick, hairy covering. The male has a well-developed upper canine tooth, which projects downward and serves as a weapon of defence.

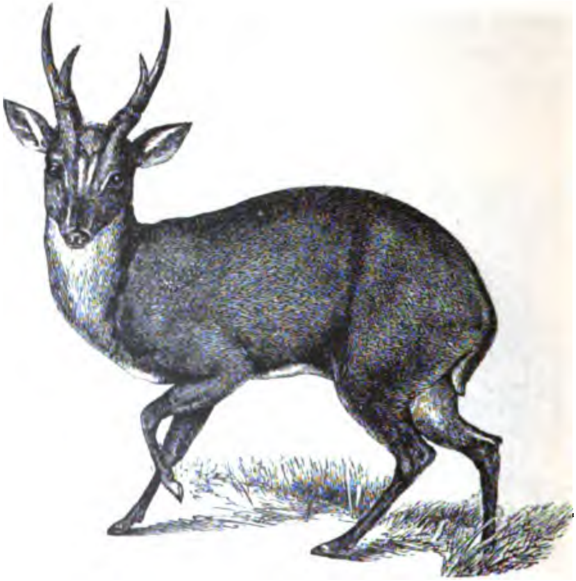


FIG. 112.—THE MUNTJAC.

The **Chinese Water Deer** *(Hydropotes inermis)* is another small member of the group of the *Cervidæ*. He has no antlers, but has a strongly developed upper canine tooth, which is like a tusk and is a very effective weapon of defence.

The **Roebuck** *(Capreolus caprea)* is also a small member of this group. He has a small antler and is more gregarious in his habits than the other *Cervidæ*. He is tamed with great difficulty and is rarely or never domesticated.

The **Chinese Elaphure** *(Elaphurus davidianus)* is a larger and more elaborately developed cervine organism. It is of a considerable size, and is restricted in its habitat, being found chiefly in China. Its antlers are well developed, and peculiar in their structure and form, and are different from those of any of the other deer family. It consists of a heavy beam rising straight from the head, and bifurcating high up into two branching points. From this beam springs an enormous back tyne, which gives the antler a curious appearance. It is an elegant example of the deer tribe, showing a high degree of development.

Another of the larger members of the group of deer is the **Reindeer** *(Rangifer tarandus)*. This animal has attained a large size, in point of anatomical growth, during the early Post-Tertiary ages. In modern times he is found in the colder zones of the earth, where he would undoubtedly become extinct were he not cared for and domesticated for the use of man. He also has a remarkable development of antler, which is heavy, broad, and palmated.

Several other varieties of the deer family are to be found in Asia, Africa, and the Indian islands, but all are divergent developments from the same original ancestor. External environment, climate, and natural selection are the potent factors that have caused the changes in anatomical configuration. In all these varieties of the *Cervidæ*, the physiological functions of nutrition, reproduction, and growth are the same. The osseous system of the whole order shows a remarkable similarity of structure and plan. Besides the groups and individuals described, there are multitudes of other forms, great and small, that need not be studied here. All of them can be clearly traced back to their progenitors, and all have followed some special line of development and descent through long ages, and have undergone the changes of form induced by their particular environment, natural selection, habits, and modes of life.

The birds have varied in anatomical structure, in color markings, and in habits, through the same influences that determined changes in mammalian forms. Habitat and its local influences have acted powerfully to induce structural changes.

This is also true of the multitude of forms of fishes. The fundamental structure of both birds and fishes has, however, undergone but few changes. The vertebrate type remains practically unchanged. The lesser points of difference have been determined largely by local causes, acting for long periods of time upon them.

The number of the mammalia now existing upon the earth is very large. If we begin with the elephants, who stand at the head of the animal kingdom in point of size, and review the line along the forms of the hippopotamus, rhinoceros, giraffe, camel, deer, elk, guanaco, llama, and the whole order of the *Felidæ*, *Canidæ*, *Ursidæ*, *Hyenidæ*, *Suidæ*, *Bovidæ*, *Rodentia*, and the multitude of other and lesser forms, we shall see a vast assemblage of animal life, which at first sight presents striking and apparently irreconcilable differences.

But in our study of the evolution of these various animal forms, we have already seen that they all have a homogeneity of anatomical structure, a similarity of plan. All are vertebrates and mammals. This great concourse of mammalian animal existence has sprung from a few forms that lived in the early Eocene period. The divergence has occurred in the subsequent ages. In the preceding Cretaceous period, no mammals existed. It was the age of reptilian forms of life. From those cold-blooded *oviparous* animals descended the warm-blooded *viviparous* mammals, by a process of change in physiological function, and a special anatomical development of special organs, which we have already studied. The first mammals were few in number, as we might conclude *a priori*, and sprang by the processes of evolution from the preceding reptilian forms. As the conditions of the earth became more completely adapted to the support of animal life, those early forms began to diverge, slowly and by almost imperceptible degrees, until, in the course of the immense lapses of time between the early Eocene ages until the Quaternary ages, a vast number of newer and higher forms finally appeared.

The geological changes that successively took place in the surface of the earth very greatly determined the evolution of animal life. If the earth had remained covered with shallow seas and low, wide-spreading marshes, reptilian life would have been the highest form of life possible. But as dry land increased in extent, and vegetation became nutritious and abundant, when in fact the earth became a vast rich pasture, watered by abundant rivers, bathed in bright sunshine, and fanned by warm and pleasant breezes, mammalian life became possible, and, under conditions so extremely favorable, animal forms diverged from the earlier types, and developed rapidly into a multitude of newer forms. The earth, in the Quaternary period, presented the same appearance that it does to our eyes. The same glorious panorama of mountain, hill, and valley, of prairie, forest, and woodland, of lakes and rivers, of trees, plants, and flowers, of sunshine and storm, of heat and cold, of seasons and of zones, existed then as now.

The same familiar animals, some fierce and dangerous, others mild and gentle, roamed over the earth —all as we see them now—except man.

The time of his evolution had not come.

In the Post-Tertiary or Quaternary age the earth was well fitted for the support of the larger forms of animal life, and we find great numbers of the bones of the **Elephant** in our country, where it once roamed freely.

This great animal descended from the mastodon and mammoth, and was a continuation of development in a later age from these ancestors.

Late in the Post-Tertiary period the American elephant became extinct, but in Asia and Africa he found a congenial habitat, where he still survives, amid vast and congenial solitudes.

The hippopotamus and the rhinoceros also found the warmer regions of Asia and Africa more congenial to their tastes, and in those sequestered countries they roam at will, finding abundant food in the rank weeds and grasses that grow so luxuriantly in those lonely and sluggish rivers.

Insect life became very numerous in the Post-Tertiary period. We have already studied the evolution of the bee, one of the earliest forms of insect life. The fly in its various forms, the mosquito, gnat, flea, the vast array of bugs, beetles, and lowly forms of winged and creeping things are divergent developments from a few ancestors.

Infusorial life is also very abundant. These tiny and often invisible organisms swarm by millions in pools and stagnant places, as well as in many liquids used in daily animal needs.

Their form is often complicated and highly organized, and they are composed of cells more or less elaborately aggregated.

Throughout the long array of animal life, from the early Cretaceous reptiles to the late Post-Tertiary mammals, we find the *brain* to be small in proportion to the size of the body of the animal. The *vertex*, or that part of the brain which contains the *gray matter*, is usually small and but slightly convoluted. This condition denotes a low degree of intelligence. The posterior part of the brain or cerebellum is usually large, and this is what we should expect, since the cerebellum presides over the function of *motion* or muscular co-ordination, and as animals are highly developed in their muscular systems the cerebellum became highly specialized in its development to preside properly over the function of motion.

The olfactory nerves are also highly developed, and, as the sense of smell is exceedingly important to animals, these nerves are frequently so highly specialized as to be developed into a *bulb*, and we find in many animals a highly developed olfactory bulb to preside over the important function of the sense of smell. As we rise higher in the animal scale until we come to the higher apes and man, we find the brain more elaborately developed. The vertex is more deeply convoluted and the gray matter more abundant, denoting a higher degree of intelligence. As man uses his brain more and his muscles less, we find the hemispheres grow larger and the cerebellum smaller. In man the sense of smell is also less important, and hence through disuse the olfactory bulbs diminish and a smaller olfactory nerve alone remains. In the earlier and lower animals *thought* and *reason* were but little needed, and hence the brain was but slightly developed. When man appeared, these two functions were of supreme importance. They made him the master of the world, and we see a special development of *gray matter* and a deeply convoluted brain surface to increase the area of this gray matter, in which reside the higher intellectual faculties.

CHAPTER XV.

POST-TERTIARY PERIOD:—THE AGE OF APES.

The Quaternary period—Bipeds or apes—Fossil apes found in Miocene or Eocene deposits—The anoplotherium the progenitor of the ape—Development of the thumb and the clavicle—North America the original home of the ape—His migrations—Platyrrhine and catarrhine apes—The cynomorpha — The anthropomorpha — Prognathia — The mandrill—Baboon—Magot—Moor macaque—Mangabey—Black baboon—The Lemuroida—The gibbons—Siamang—The agile gibbon—Wooyen—Hoolook—Orang utan—Chimpanzee—Koola kamba—Nschiego mbouvé—Gorilla—His anatomy compared with that of man—His change to a gorilla-man, and finally to a black man.

We have studied as far as necessary in the preceding pages the development of animal *quadrupeds*, or those animals using *four* limbs in the act of locomotion. We now have to consider a class of animals differing from them in some important particulars—namely, the *apes*.

While the earlier and more lowly forms of apes were *quadrupeds*, using both anterior and posterior limbs for locomotion, the later and more highly specialized apes were true *bipeds*, using the posterior limbs only for locomotion, and the anterior limbs for prehension, I have, for the sake of convenience, classed them all under the name of *bipeds* or apes.

The term "age of apes" is also only a matter of convenience, while treating of the evolution and development of these animals. It is an arbitrary term used here to designate a period of time when these animals reached their greatest point of development.

Fossil apes were at first found only in early Miocene formations, and it was believed that they appeared in that age, but later searches have found them in a lower horizon, in the late or upper Eocene period. These early apes were very dog-like in form, and of lowly organization, and it is extremely probable that they sprang from the same ancestor as the dogs—namely, the anoplotherium of the early Eocene age.

This animal soon diverged in structure and, under favoring circumstances, gave rise to a series of dog-like forms, as the hyenas, dogs, and dog-like apes.

We have already studied the evolution of the early hyenas and dogs, and we have seen that a still further divergence from their progenitor gave rise to another animal closely resembling them—namely, the ape. We have also seen how a slight change in physiological function could transmute him to a fruit-eating animal, and that to obtain fruits he must seek them in trees. This would compel him to lead a more or less complete arboreal life, and this again would of necessity lead to the development of special modifications of limb to enable him to live and move with safety among the branches of trees. These modifications of limb consisted in the adaptability of the anterior extremity to grasp and to hold an object. The *need* to perform a certain act led to the special development of parts to enable him to perform these certain acts, and under the stimulus of this need we see the first digits of both anterior and posterior extremities gradually become *opposable* to the other digits.

In this way, and under the law of use, we see the development of a *hand* with an opposable *thumb*. In the early dog-like apes this opposability was slight, and the fossil bones show only a small degree of divergence from a straight line of the carpals, metacarpals, and phalanges in the anterior extremities, of the tarsals, metatarsals, and phalanges in the posterior extremities. Slight as this divergence of bone in the hand was in the early apes, it was sufficiently powerful to induce another anatomical change of great importance—namely, the development of a clavicle.

In a true quadruped a clavicle is not needed, and therefore does not exist. The anterior limbs simply support the weight of the forward part of the body, and are used for locomotion, and not prehension. The head of the humerus is received into the shallow cavity of the scapula, and the motion is a forward and backward swinging motion.

The scapula, which is a broad, flat, triangular-shaped bone receives the upward thrust of the head of the humerus against its apex, which is pointed downward when the animal is in motion, and it is held in place against the sides of the thorax by muscular attachments. It is a part of the locomotory apparatus.

In the apes who use the arms and hands for prehension as well as locomotion, we find a clavicle. The development of this bone was induced by a special need of the animal to keep the shoulders apart when in the act of climbing. A bone was formed to meet this special need, and to perform this special function. The clavicle cr collar-bone is of a slightly curved shape, with the outer end articulated to the acromion process of the scapula, and the inner end to the upper border of the sternum or breast-bone.

The development of this bone marked the difference between the clavicular and the non-clavicular animals, and was a long step in advance in animal evolution.

In the apes, then, we have an anterior limb, which is fitted for locomotion and for the vastly higher office of prehension, and at the extremity of this limb we have a hand with an opposable thumb and four fingers capable of free flexion. This gives the animal a free use of his limb, and, with the slightly opposable great toe of the posterior extremity, or foot, enables him to perform, with ease and safety, the higher functions incident to an arboreal life. The development of a clavicle, of a hand, and of a hand-like foot places him far in advance of the other members of the animal kingdom.

The evolution of the ape occurred in our own country. In later ages, probably in late Pliocene time, he migrated in two opposite directions. First, south along the pathway of the Isthmus of Panama, or along the great highway of what are now the Windward Islands, to South America. Here he diverged slightly and developed slowly, and gave rise to but few varieties of no special importance. The subsequent elevation of the Andes Mountains and the breaking up of the great highway of land into islands made his return to his native land impossible, and he has remained there ever since. Second, north over the Behring bridge of land, or the great Arctic Archipelago, to Asia and Africa. In these vast and remote regions he found an especially congenial habitat, where he diverged and developed rapidly into the higher and man-like forms soon to be studied.

The subsequent formation of Behring's Straits and the Arctic Glacial period effectually prevented his return to his original home, and he became extinct in North America.

We have already sufficiently studied the South American apes. We will now turn to those of the Old World.

At first sight there seems to be a great variety of these animals possessing anatomical characters that separate them widely from each other. As we study them closely, however, these differences appear less great, and we see they are the result of divergent development from a common ancestor, determined usually by local causes.

The apes that originally migrated to South America were very dog-like in many of their anatomical characters, and one of these was the wide lateral nostril, with a thick gristly septum.

This form of nostril has been called the *platyrrhine*, because it is wide or flat. It is rarely seen in any other ape.

The apes of Asia and Africa have a nose less widely expanded and with a thin septum. These have been called the *catarrhines.*

These great catarrhine apes may be divided into two general classes as follows :

The **Cynomorpha,** or **Dog-like Apes.**
The **Anthropomorpha,** or **Man-like Apes.**

We have seen that the dog-like apes first appeared in the early Miocene period, or perhaps in the late Eocene period. We have ample reason to believe that they were a divergent development from the anoplotherium, along with the hyenas and dogs, and all three animals then closely resembled each other. Each followed, in subsequent ages, an ever-diverging line of development, until many varieties were produced,—especially of one form—the apes.

After the migration of these animals from North America to Asia and Africa, and their permanent detention in those countries by terrestrial causes, they found the conditions of life such as to induce a still wider divergence of special form. Even with this wider divergence, some retained the original dog-like characters, while others, under a special stimulus, assumed more man-like characters.

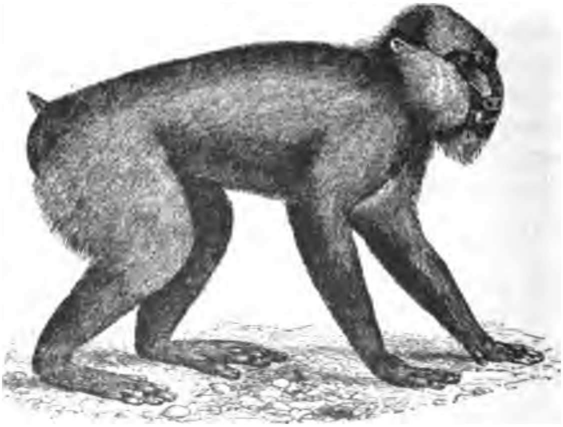


FIG. 113.—THE MANDRILL OF AFRICA.

All the apes belong to the class **Prognathia,** or those animals having a forward extension of the jaws, or prolongation of the lower part of the face.

Among those forms that seem to have diverged the least in development from the early dog-like animals was the **Mandrill** *(Cynocephalus mormon).* A view of this animal in Fig. 113 shows that he possesses many dog-like characteristics and does not differ as widely from the dogs as many of the other forms of ape.

The mandrill stands low in the scale of apes and closely resembles the carnivorous dogs. He assumes the horizontal position and uses his arms for locomotion. His powers of prehension are very limited. As he is a dweller on rocky and open ground and rarely frequents forests, his arboreal habits are very limited, and as a consequence we find his thumb lying parallel to his fingers, and but slightly opposable to them. His toe-thumb also is nearly parallel to his toes. His canine teeth are large and powerful, and his jaws are decidedly prognathous.

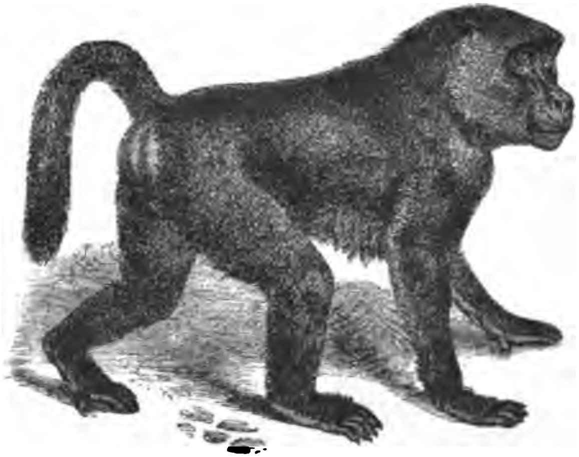


FIG. 114.—THE COMMON BABOON OF AFRICA.

His diet is mixed and partly insectivorous, and his digestive organs comparatively simple. As he is probably the earliest and oldest of the apes, he retains many of the habits of the canine quadrupeds, as well as many points of anatomical identity. His physiological functions are entirely mammalian. His intelligence is limited, owing to a small development of the cerebrum or brain proper and a small amount of gray matter and superficial convolutions. The posterior lobes of the brain do not completely cover the cerebellum. The latter is large, as we might expect in an animal so muscular and active. He has brightly colored cheek callosities, and well-marked callosities on the ischial bones.

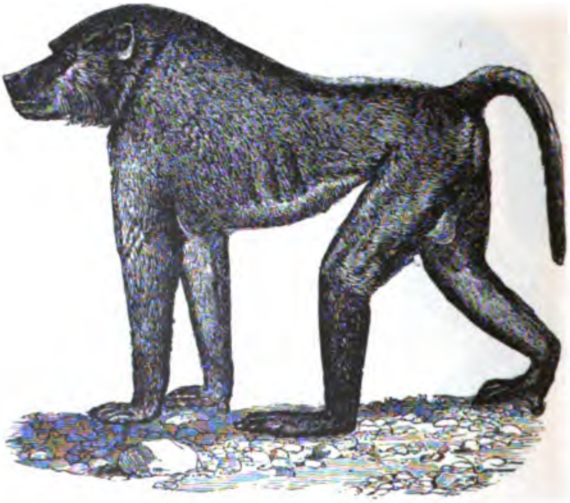


FIG. 115.—THE ANUBIS BABOON OF AFRICA.

His habitat is the rocky plains of Africa.

The **Common Baboon** *(Cynocephalus papio)* is another member of this dog-like group of apes. This ape has a more perfectly opposable thumb and toe-thumb than the mandrill. He has also a long bushy tail, which has not yet undergone any special atrophy.

In Fig. 114 we see the common baboon.

This ape inhabits the hilly districts of Western Africa, and rarely seeks the forests. He runs on all-fours, and retains many of the early dog-like characters. His prognathous jaw and small skull denote a low degree of intelligence.

The **Anubis Baboon** *(Cynocephalus anubis)* belongs to the same group of dog-like apes. His nose is exceedingly like that of a dog, but his arms are rather more perfectly developed.

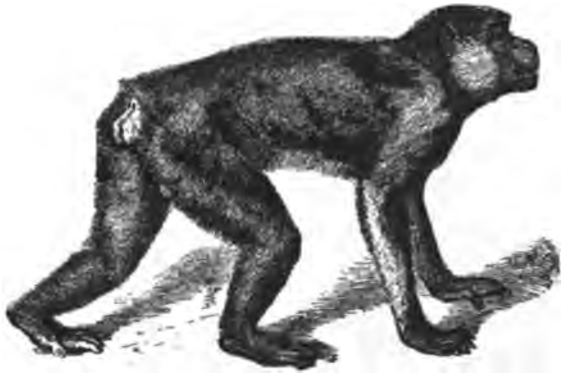


FIG. 116.—THE MAGOT OF AFRICA.

His arms are used for locomotion, and not for prehension.

The **Magot** *(Macacus sylvanus)* is a baboon, and belongs to the cynomorpha or dog-like apes. He also lives in open plains and on rocky ground in North Africa. While he habitually runs on all-fours, in a trotting and galloping gait, he can also assume the *erect posture* for a time, and can climb in trees with a considerable degree of freedom. Hence we see a more complete development of thumb and toe-thumb to meet this need. He has no tail, no cheek callosities, slight cheek pouches, and is rather more *ape-like* than the baboons.

The **Moor Macaque** *(Macacus maunus)* rises a little in the ape scale. He is found in the island of Borneo, and is distinctly arboreal in his habits. His toe-thumb is especially well developed, and, while his position is usually horizontal, he can easily assume the erect posture.

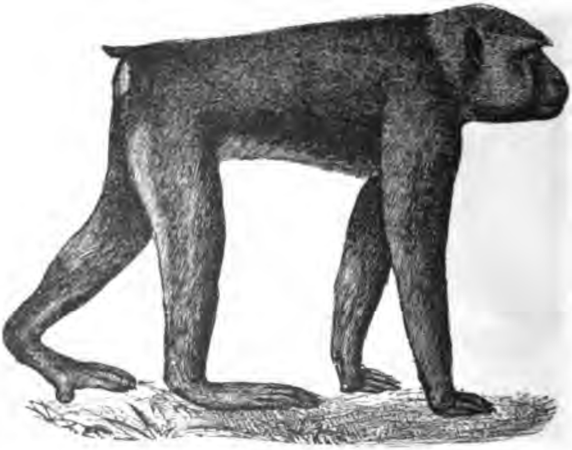


FIG. 117.—THE MOOR MACAQUE OF BORNEO.

His anterior limb begins to assume the form and functions of an *arm*. His general character is tending to a higher form of ape-life.

The **Mangabey**, or white eyelid monkey *(Cercopithecus Æthiops)*, rises a little higher still in the monkey scale. He is a little in advance of the mandrill, and is more pithecoid in character.

This animal is strictly arboreal in his habits, and as a consequence he has a well-developed thumb, and toe-thumb. In the foot the toes are webbed, especially the second and third toes, and the toe-thumb stands widely from the foot. The tail is long and non-prehensile. The foot and hand of this animal are seen in Fig. 119.

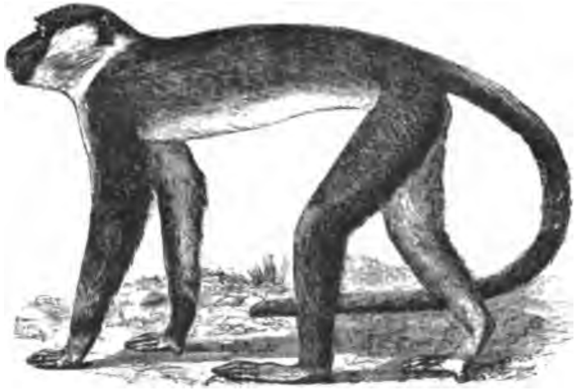


FIG. 118.—THE MANGABEY OF AFRICA.

The **Black Baboon** *(Cynocephalus niger)* is an ape of a still higher grade of development. While he is usually classed with the dog-like apes, we see he differs from them in several essential points. He assumes easily the upright position. His face is less prognathous, and he has a fairly well developed upper lip. His nose has lost the dog-like muzzle and has a shape approaching the human nose. He has a pointed tuft of hair on the head, but the skull is well formed, and his brain is of good size.

He is arboreal in his habits, and the feet and hands are well developed. While he habitually runs on all fours, he easily assumes the upright posture, and prefers sitting to crouching.

He is very intelligent, and has a docile and affectionate nature. He is rather melancholy in his disposition, and many traits of his character approach very closely to those of man.

All of the cynomorpha or dog-like apes are of medium and small size. There is a considerable variation in external anatomical configuration and development. Some have tails, as the mangabey, the Anubis baboon, the douc, the colobos verus, the toque, and the macaques, as well as many other varieties; and some have only a mere rudiment or stump, as the mandrill, the magot, the Moor macaque, the black baboon, and others. The tail is in no case prehensile, and hence is of no use in his arboreal life. In this group of apes the posterior limb or leg is *longest*, and the anterior limb or arm is *shortest*. All have the opposable thumb and toe-thumb, but the degree of opposability of these digits is greatly determined by the more or less complete arboreal life the animal leads. Those that lead a life

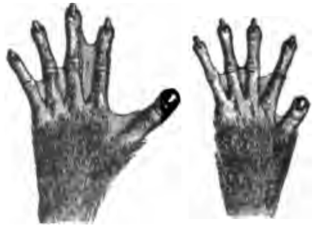


FIG. 119.—FOOT AND HAND OF MANGABEY.

in the open and hilly country have less completely developed thumbs, owing to disuse, than those who lead a strictly arboreal life in the great forests.

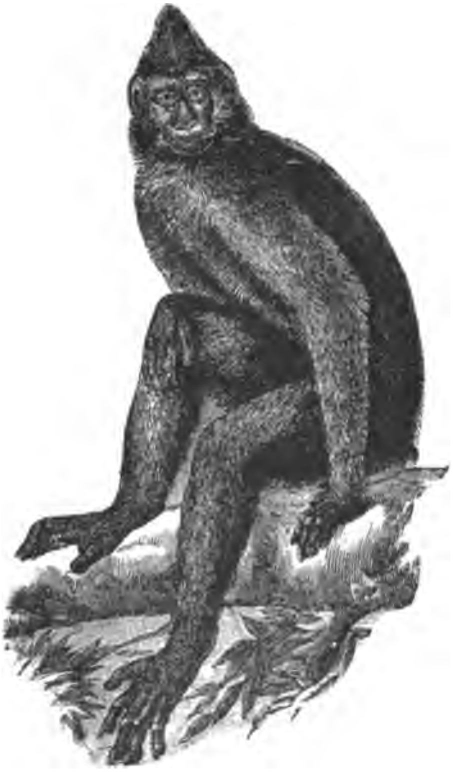


FIG. 120.—THE BLACK BABOON OF ASIA.

Some of these dog-like apes have cheek pouches and some do not. This is merely a special development of the buccal tissues to enable the animal to temporarily store a quantity of food. Most of them have *pads* upon the posterior part of the pelvic bones, where the animal sits. Some of these pads are brightly colored, owing to a special vascularity of the parts. These pads consist of a patch of the integument that becomes more or less thickened by the use of the part in sitting.

These dog-apes have a small skull and hence a small brain cavity, which denotes a medium degree of intelligence. The brain is slightly convoluted, and the quantity of gray matter is small. The jaws are prognathous, and the dentition varies in no important respect. Some have an air-sac or laryngeal pouch. In most, the stomach and intestines are simple, but in some, notably the long-nosed monkey (*Semnopithecus nasalis*), the stomach is more complex, there being three gastric pouches united together. The physiological functions of these apes are precisely the same. Reproduction, nutrition, growth, and repair are carried on in the same manner in all.

When we study comprehensively the group of dog-like apes, which numbers many varieties, and which seem at first sight to differ very widely from each other, we shall observe, upon a closer scrutiny, that all of them are anatomically related, and we must believe that all of them sprang from a common stock. In their migration from North America to Asia and Africa they dispersed gradually over almost limitless expanses of country. Here, finding favorable although differing conditions of life, they had ample time and sufficient cause to vary in their development, until finally the evolution occurred of all the varieties of this special group we now see. Some of these apes continued their migrations to Madagascar and the other great islands of Africa and Asia, when those islands were connected with the continents. A subsequent separation of these islands, through geological changes, isolated these animals, and through the influence of climatic and terrestrial environment, they slowly changed and diverged in development, and gave rise finally to the group called the *Lemuroida.*

These are ape-like animals, having some individual anatomical peculiarities, which are interesting to the naturalist.

They inhabit a restricted territory, and are comparatively few in numbers.

Following the **Cynomorpha,** or dog-like apes, come the **Anthropomorpha,** or man-like apes. This group contains those great ape-like forms that so closely resemble the animal called *man.*

If the dog-like apes sprang from the anoplotherium of the early Eocene period, from what animal did the man-like apes spring? Undoubtedly they were a continuation of development, and a more special degree of evolution of the higher dog-like apes.

In the dog-like apes we have seen that the leg was longer than the arm, and that some had tails and some had not.

In the man-like apes the legs are shorter than the arms. In the lower ranks of these animals—namely, the gibbons—the arms are long enough to permit the hand to touch the ground without bending the body. This great length of arm is a special development to meet a special need. The habits of this animal are strictly arboreal. He delights to seek the highest tree-tops, and in order to swing among the branches with celerity and ease, he needs a long arm. This is an *adaptive* growth of parts to enable the animal to do a special thing.

As we rise higher in the scale of man-like apes, we find these higher forms living more upon the ground, and, as they use their arms less in swinging in the trees, the arm shortens, by the law of disuse.

The lowest of the man-like apes is the genus *Hylobates*, which means a walker in the woods, and to this genus belong the *Siamangs* and the *true gibbons*.

These two apes seem to occupy a neutral ground between the highest dog-like apes and the lowest man-like apes.

The **Agile Gibbon** *(Hylobates agilis)* is one of the lower of the man-like apes. He maintains the erect position in walking, but in doing so he uses his hands to aid him. His arms are very long, so that his hands can touch the ground. He is strictly arboreal in his habits, and this great length of arm permits him to swing easily among the higher branches of the trees. In the higher apes and in man there are eight bones of irregular shape composing the carpus or wrist. In the gibbon there are nine of these carpal bones. In this animal, the thumb and toe-thumb are well developed, and covered with a *flat* nail, the fingers and toes are armed with a more claw-shaped nail.

The skull is fairly well developed, but, in an animal so active, the brain or cerebrum is less fully developed than the cerebellum, which specially co-ordinates muscular motions. This part of the brain protrudes backward, and is not completely covered by the lobes of the hemispheres. The jaws are less prognathous than those of the dog-like apes. The teeth are well developed, and adapted for a mixed diet. The canine teeth are small. In Fig. 121 we see this animal.

He rises a little in the scale above the dog-apes, and presents some characters that are decidedly human.

This ape is found in India, and, in Post-Tertiary times, he ranged over a large part of Asia and Southern Europe. The hand of the gibbon is very flexible.

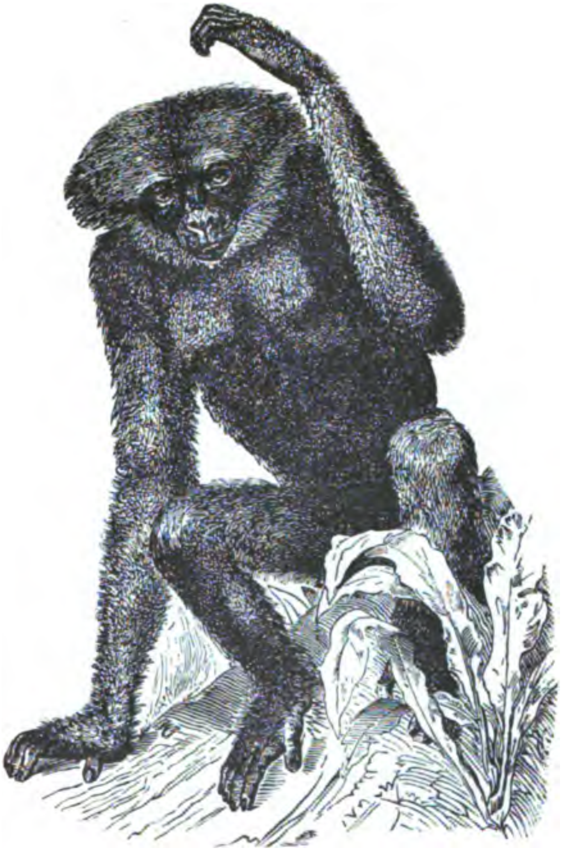


FIG. 121.—THE AGILE GIBBON OF INDIA.

The **Wooyen Ape** *(Hylobates pileatus)* and the **Hoolook** *(Hylobates hoolook)* are two man-like apes occupying a step higher still in the simian scale than the gibbons.

They have the same length of arm as the gibbons, and resemble them in their general anatomical structure, habits, and modes of life. Their habitat is Southern Asia. They also are very human in many of their characters, and display considerable intelligence.

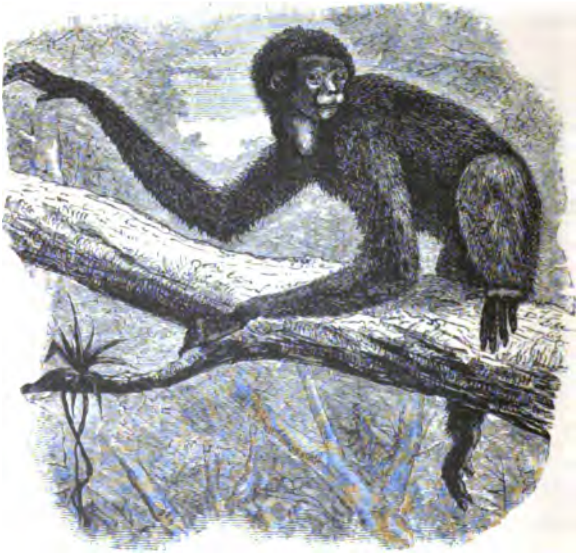


FIG 122.—THE SIAMANG OF ASIA AND SUMATRA.

The **Siamang** *(Hylobates syndactylus)* rises still above the gibbons, and is very human in many of its characters. It learns with great facility to perform many domestic acts with curious dignity. Its long slender arms enable it to swing easily among the treetops, where it delights to dwell. The first and second fingers are webbed nearly to the tips. The brain is well developed, but does not wholly overlap the cerebellum, which is large and strongly developed, as it is

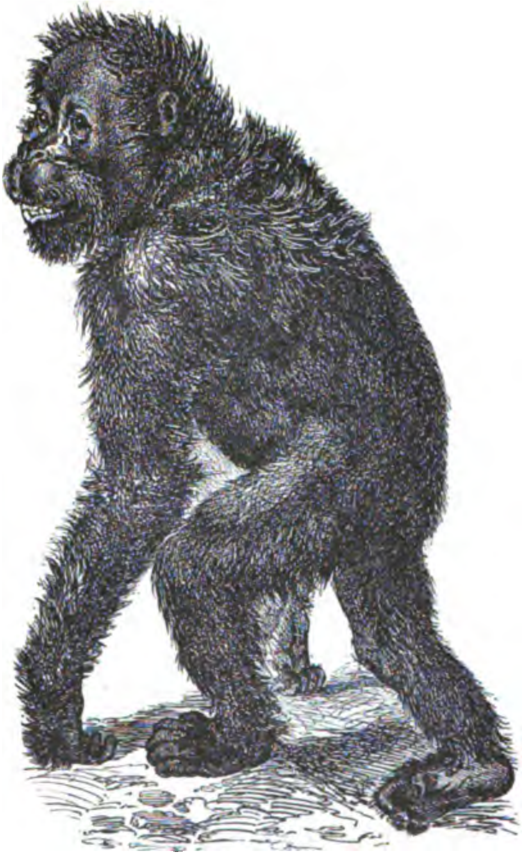


FIG. 123.—THE ORANG UTAN OF SUMATRA AND BORNEO.

in all animals of great muscular activity. The chin is more rounded and human than in the other apes. This interesting ape can easily walk erect, and usually maintains this position, aiding himself when necessary with his hands. He has fourteen pairs of ribs, and his round shoulders, flat shoulder-blade—scapula,—broad sternum, and slender muscles give him a very human appearance. He is fond of milk, and is easily tamed. His habitat is Southern Asia and the island of Sumatra.

The **Orang utan** *(Simia satyrus)* "The Wild Man of the Woods," advances rapidly in the simian scale. He is decidedly man-like in his external configuration and anatomical structure. While he is one of the prognathia, we see a less prominent jaw than is seen in the dog-like apes.

The orang walks habitually in the erect posture, and while his habits are largely arboreal, he is also a dweller upon the ground. His arms are long, and the hands nearly touch the ground. They are well developed, and the thumb is large and freely opposable to the fingers.

The toe-thumb is especially well developed. The brain is large and convoluted, and covers the cerebellum. As this animal rises above the siamang in intelligence the brain is larger, the convolutions deeper, and the gray matter greater in quantity.

As he is less active, the cerebellum is smaller and covered by the posterior lobes of the brain.

As in man, the orang has but twelve pairs of ribs, and his muscular development and digestive apparatus are very human. This great man-ape is found only in the great tropical islands of Sumatra and Borneo. These immense areas of land lie directly under the burning sun of the equator, and the climate is, therefore, perpetually torrid. Sumatra stretches away a thousand miles in luxuriant fertility, and Borneo exceeds eight hundred miles in length. Both these vast islands of tropical verdure were, in a former age—the Tertiary—connected with the Malay Peninsula, and at that epoch the apes were able to migrate from the continent of Asia to these immense and fertile regions. A subsequent separation of this land, through geological changes into islands, isolated these apes from their fellows, and they have had ample time in the long succeeding ages to undergo, amid favorable surroundings, the changes of bodily structure necessary to

FIG. 124.—THE CHIMPANZEE OF AFRICA.

transmute them into the man-like shapes we now see them.

The **Chimpanzee** *(Troglodytes niger)* ascends still higher in the scale of man-like apes. This dweller in the great forests of equatorial Africa is very human in appearance and reminds us that we are gradually approaching that higher animal—man—in the scale of evolution.

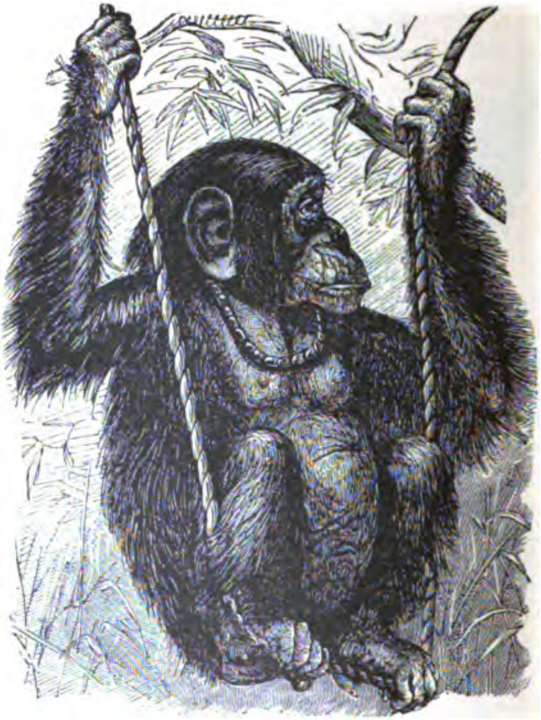


FIG. 125.—A TAME CHIMPANZEE SWINGING.

The chimpanzee has several anatomical points which distinguish him from the apes below him. His arms are shorter, reaching but a little way below the knee. His dorsal, pectoral, and brachial muscles are well developed, and his power of grasping with the hand is like that of man ; he clasps his thumb around the object grasped instead of keeping it nearly parallel to the fingers, as is the case with the orang and many other apes. His hands are bare.

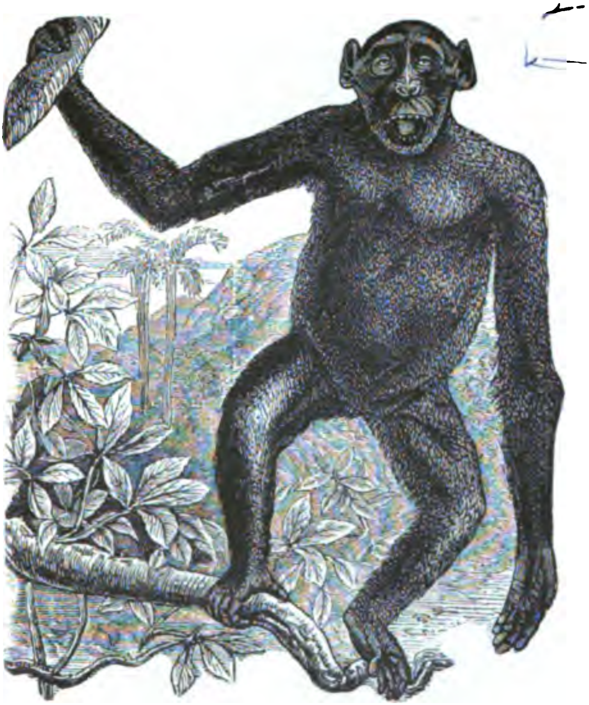


FIG. 126.—THE KOOLA KAMBA OF AFRICA.

His chest is large and protected by thirteen pairs of ribs. His legs are fairly well developed and enable him to maintain the erect position with ease. His feet, which turn inward a little, are bare, and his toe-thumb strongly opposable to the foot. His brain, which specially elevates him above those below him, is well developed, deeply convoluted, and covered with a well-marked layer of *gray* matter. This gives him a remarkable degree of intelligence. The chimpanzee *Crowley*, that was kept for several years at the Central Park menagerie, was noted for his very human intelligence. He was taught to sit at table with great dignity, to tuck a napkin under his chin, and take his soup with a spoon from a plate. When he took food in his fingers he did so delicately, and cleansed them at once on his napkin. He expressed the emotion of joy by laughing, and of sorrow by shedding tears. His anger was shown by a scowl, an impatience of manner, and by stamping his foot upon the ground. He showed his love for "Jake," his keeper, and for his friends by a marked tenderness of manner. He would hold my hand softly in his and kiss it, and show his friendship for me by a pleased expression.

The chimpanzee's brain overlaps the cerebellum as in man. The nerves of *special sense* and the sensient and motor nerves are well developed. His teeth, mouth, and palate closely resemble those of man.

Rising still higher in the scale of apes, and surpassing the very human-like chimpanzee, we come upon a rare and singular animal who is very man-like in configuration. This is the **Koola Kamba** *(Troglodytes Koola Kamba)*, a dweller of the sequestered forests of equatorial Africa. This great ape is very human. He has a shapely round head, large ears, open expressive eyes, and a wide mouth. The rounded chin and the contour of the face give him a strong resemblance to man.

His habits are purely arboreal, hence the strong muscular arm, the well developed and flexible hand, and

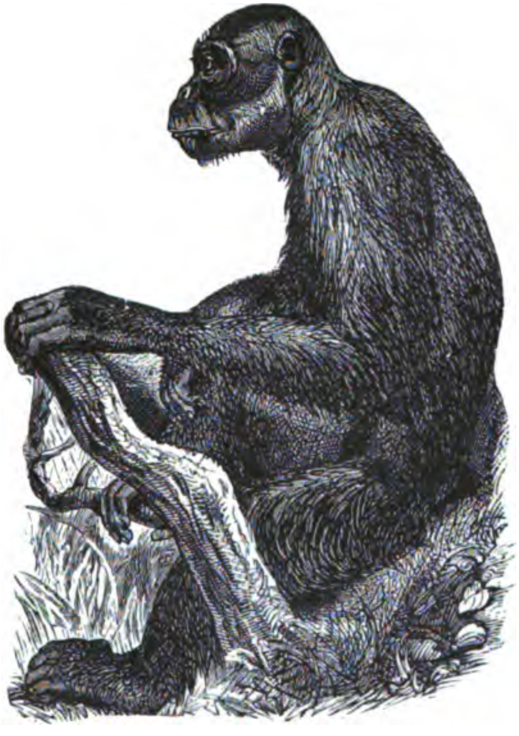


FIG. 127.—THE NSCHIEGO MBOUVÉ OF AFRICA.

the grasping foot. He habitually maintains the erect position, and has, in consequence, well developed muscles of the hip, leg, and foot. He possesses considerable intelligence, and is regarded by the natives as a very human creature.

Another ape which stands between the chimpanzee and the gorilla is the singular animal called the **Nschiego Mbouvé** (*Troglodytes Tschiego*).

This rare ape has his habitat in equatorial Africa, where he seeks the seclusion of the densest forests. He is a large man-like animal, having a bald head, well-shaped skull, with very prominent supra-orbital ridges. The eyes have a quiet expression, and the cerebral hemispheres are well developed and convoluted. His arms reach a little below the knee, and are muscular and powerful. His habits are arboreal, and hence he has a well-formed opposable thumb and toe-thumb. He maintains the erect position with comparative ease when walking. He has thirteen pairs of ribs, and a well-formed thorax. His bony skeleton is very human in its structure, and his general configuration closely resembles that of man.

At the head of the group of the great man-like apes, and standing above them all in the animal scale, is that important and well-known creature the **Gorilla** (*Troglodytes gorilla*). He is the largest of all the apes, and his special anatomical structure places him in the scale of evolution next below man. His habitat is the almost boundless forests of Africa lying under the fierce tropical sun of the equator. Here, amid a favorable environment and free from hostile influences, he has developed in the long flight of the ages from a preceding lower form into the large man-like animal now seen.

As the gorilla's place in nature is so close to that of man, and as the organic structure of both is so strikingly alike, it will be a subject of the highest interest to study the more salient features of his anatomical form. Upon looking at a full-grown male gorilla we see a large powerful animal which at first sight appears to differ from any other animal. He is considerably in advance of any of his fellow-apes. If we examine him closely we shall see that he is very man-like in his construction and general configuration.

His skull is small in its cranial capacity and his jaws are prognathous. The lower molar teeth are set in a straight row and this causes the jaw to project strongly forward. The canine teeth are large and powerful.

The brain is about two thirds the size of the human brain. The fissures and convolutions and shape of the hemispheres closely resemble the brain of man. The internal cerebral anatomy is also practically the same. If we take the brain of the gorilla and divide it on a horizontal median level, we shall lay open the two spaces called the *lateral ventricles.* These are separated as in man by the *septum lucidum.* Each ventricle—the right and left lateral—has an anterior and posterior cornu or horn-shaped point extending into the substance of the brain. Upon the floor of each ventricle are seen two curved irregular-shaped eminences or bodies, the *hippocampus major* and *hippocampus minor.* They are the same as in man.

In the gorilla's brain are found the *corpora striata* and the *optic thalami.* Each optic thalamus gives origin to bundles of nerve fibres that go to form the *optic nerves*, and these nerves form a *commissure* as in man. The olfactory and fifth pairs, as well as the eighth pair, or pneumogastrics, are given off in the same way from the under surface of the brain, and have the same physiological functions. The posterior lobes of the cerebrum overlap and cover the cerebellum.

In all the more important anatomical cerebral structures and physiological functions, the brain and nerves of special sense in the gorilla correspond with those of man.

The hard palate forming the roof of the mouth is very narrow and constricted, and the buccal cavity itself is greatly contracted. The tongue is in consequence long, thin, and narrow, and this makes articulate speech impossible in the gorilla.

The strongly developed larynx gives the gorilla the power to utter deep guttural sounds.

The arm and forearm are much longer and more muscular than in man. The deltoid, biceps, and triceps muscles are large and strongly developed, as we should expect to find in an arboreal animal. The rotation of the radius upon the ulna is free, but not so perfect as in man. The flexor and extensor muscles of the hands, and the opposability of the thumb also closely resemble our own. The hand itself is very human, and can easily grasp and hold objects with the thumb and fingers clasped about them. The thorax is capacious, and the lungs well developed. The ribs number thirteen pairs. The heart and blood-vessels, the stomach, liver, pancreas, spleen, and the intestines are like those of man, and have exactly the same physiological functions.

In the muscles of the lower extremities we notice considerable differences. The gorilla is unable to maintain the erect position in walking as perfectly as man, but is obliged to aid and steady himself by means of his hands, which he frequently applies to the ground.

This imperfect upright position of the gorilla is owing to the lesser development of the muscles of the hip, thigh, and calf. In order to stand securely in the erect position, the glutei muscles of the hip must be well developed, as well as the psoas and iliacus muscles of the inner side of the thigh, and the quadriceps extensor muscle of the front of the thigh. In man we find all these great muscles well developed, and hence he can stand erect with ease. In the gorilla and the lower apes the glutei muscles are but slightly developed, and hence the upright position is only partially maintained. The act of walking is further maintained by the gastrocnemius muscles of the calf of the leg. In man we find these muscles thick and fleshy, and they perform the office of locomotion perfectly. In the gorilla and the lower apes these muscles are thin and tendinous, and are better fitted for an arboreal than a terrestrial life.

The gorilla finds another difficulty in walking in an erect position—namely, his inability to bring the plantar surface of the foot, or sole, flatly upon the ground.

His forestine life for ages has led him to seek his food from fruits and nuts, and in order to obtain these to satisfy his daily needs, he must find them among the trees. A special need to aid him in holding on to the branches was thus called into activity, and the great development of the toe-thumb was the result. This toe-thumb has the power to clasp itself around the branches of trees, and as a consequence the foot is thrown more or less upon its outer edge in walking. This inability to apply the sole of the foot flatly upon the ground, together with the only partial development of the glutei and crural muscles, is the reason why the gorilla walks with a somewhat uncertain gait, and is obliged to steady himself, while in an upright position, by the use of his hands and long arms.

In his native state the gorilla displays some intelligence in his search for food. His slight reasoning faculties lead him to throw clubs and stones to dislodge a fruit or nut from an inaccessible tree-top. He also partially defends himself from his enemies by the use of a club or by throwing missiles. In captivity he easily

FIG. 128.—THE GORILLA OF AFRICA.

learns to use a cane in walking, and has been taught to bathe his hands and face, and to make some effort at personal adornment. In Fig. 128 we see the gorilla in his native forests.

While the gorilla is often described as a wild and savage beast, he nevertheless has some kindly and excellent qualities, and often displays the human attributes of affection and regard for those who are kind to him. In comparing the structural anatomy of the gorilla with that of man, we see superficial and external differences that at first view seem so great as to place an impassable gulf between them. These differences, in point of brain capacity, of contour of face, of length of arm, of non-developed muscles of the hip, thigh, and leg, and of the shape of the foot, are very

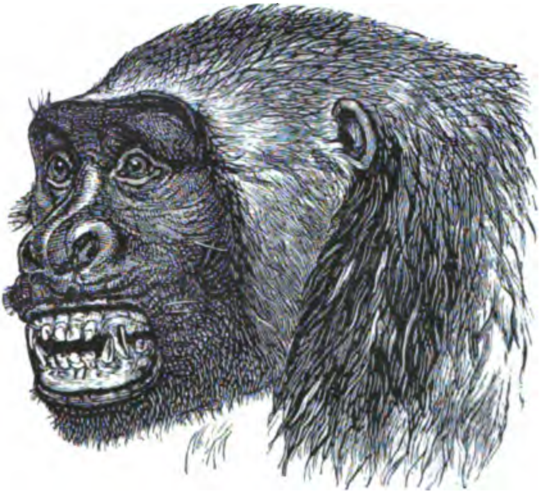


FIG. 129.—FACE OF THE GORILLA.

great. But the two animals approach each other very closely when we examine the important anatomical organs of both. The internal structure of the brain of the gorilla is like that of man. The origin and functions of the nerves of special sense are alike. The physiological functions of the digestive and reproductive systems are the same, and the osseous structure closely similar.

The gap, as we now see it, between the highest apes and the lowest men, was very much less in past ages. There were undoubtedly transition forms between the gorilla and man which might be called *gorilla-men*. In the evolution of the gorilla he must have changed slowly in his bodily configuration as he gradually emerged from his forest home and led a more migratory life upon open ground. These changes would show themselves first in a more erect position of the animal, then a development of a flatter foot, and the change of the toe-thumb to a straight toe. Next would follow of necessity a shortening of the arm through disuse, for at a certain stage in his career he ceased to be an arboreal animal—a tree-climber—and became a migratory animal upon the surface of the ground. Last of all came a change in his skull and an increase in the size of his brain.

These changes of bodily form were a necessity and were due to a change of habitat imposing new conditions of life upon the animal. His slow emergence from his form of a gorilla to the more advanced gorilla-man, and finally to a black man, was an orderly, gradual, sequential process, requiring long ages to accomplish such a series of important changes.

CHAPTER XVI.

POST-TERTIARY PERIOD:—THE AGE OF MAN.

The Quaternary period—The evolution of man—The gorilla his progenitor—Changes in his skull, brain, arm, leg, and foot—His migration to the north—Confronted by new enemies: the lion, panther, leopard, python—Food: mango, banana, date, maize, rice—Invents weapons—Discovers fire—A cooler climate whitens his skin and straightens his hair—He reaches the Mediterranean Sea—Learns cookery—Settles in the valley of the Nile—Early civilization of Egypt, Asia, Greece, Rome, Northern Europe—Penetrates to Malaysia and Australia—Migrates to North and South America—Races of men—Evolution no longer active—Modern destruction of life—Progress of man—His intellectual development—Science—Medicine—Steam—Electricity—Chloroform—The influences of war, disease, vice—Time since the earth has existed.

THE EVOLUTION OF MAN.

DURING the early ages of the Quaternary period a new form of animal life appeared upon the earth. It was a product of evolution from some preceding lower form resembling itself in its general configuration. This new animal, which was able to assume the erect position permanently, and which could use its hands for performing acts of precision and intricate prehension, has been called **Man** *(Homo)*. When we study the anatomy of this new animal, we find it has certain characters and qualities which became familiar to us in our study of the higher apes. It has a round skull with a large cranial cavity, containing a well-developed, deeply convoluted brain and a small cerebellum, which is completely overlapped by the posterior lobes of the brain lying above. The jaws are but slightly prominent, the chin rounded, and the canine teeth small. The thorax is well formed. The ribs number twelve pairs. The ilia, or hip-bones on either side, are broad and expanded, forming a wide pelvis and giving a large surface of attachment to the glutei muscles that aid him in maintaining the upright position. The arm and forearm are short and slender, and the hand highly developed. The muscles of the thigh and leg are thick and fleshy, which greatly aid him in upright locomotion. The foot is straight, and flat on its under surface. The great toe lies parallel to the straight bones of the foot instead of being at an angle from the foot, as in the case of a toe-thumb. This animal could use a club in his hands with dexterity and ease, and could construct a rude shelter for himself from the sun and rain. His food consisted of grains, fruits, and nuts, and he could gather them with ease by the aid of his superior intelligence, his habitually upright position, the use of his mobile hands, and his rapid locomotion made possible by his straight foot with its flat plantar surface. This new animal — this early *Homo*—had thick lips, curly hair, and a very black skin. The appearance of such an animal at once excites our interest and leads us to inquire from what preceding form was he descended; what previously existing animal was his progenitor.

The answer is simple. There was but one animal from which he could have descended—that was the great man-like ape, the gorilla, of equatorial Africa. If this is true, and scientists generally admit its truth, what special causes sprang into activity to transmute such an animal as the gorilla—a man-like ape—into what probably was at first an ape-like man?

These causes were many and distinct.

We have already seen that this great ape, the gorilla, dwelt in the thick, sombre, tropical forests of equatorial Africa, and that his food consisted of fruits and nuts. To obtain these for his daily needs he was obliged to ascend into the trees to get them, and he was therefore by necessity an arboreal animal. Such an animal, leading a life among the trees, had a special kind of labor to perform, and under the law of the *adaptiveness of nature*, a special development of the jaws, arms, chest-muscles, and a prehensile foot with a toe-thumb followed as a natural result. In this condition as a tree-dweller he remained for a long period of time.

In the course of the ages, however, the gorilla began to diverge in his anatomical structure in obedience to the law of advancing development, and the higher needs of the animal induced by the *new conditions* imposed upon him by migration, which led to newer habits and different modes of life, and a change in the nature of his food. All these have been proved to be powerful factors in the problem of the evolution of life. While the gorilla remained an arboreal dweller in the great African forests lying under the equator, he must continue to be only a gorilla indefinitely. No higher development could be possible under his old forestine conditions. But a slight northward migration away from his former scenes induced a structural change immediately by bringing him under the influence of a newer mode of life. Above the tenth degree of north latitude a new condition of life is met with. At this geographical point, the climate begins to change, and new food-products are found in rich abundance. These are the mango, banana, date, maize, and rice.

The migration of the gorilla from his sequestered forestine home to more open lands and distant places at once and inevitably induced a special change in his bodily structure. The toe-thumb being no longer needed for arboreal prehension, under the new stimulus of locomotion on open and uneven ground, soon lost its opposability and ultimately assumed a position parallel to the other toes, and in time a straight, even foot with a flat plantar surface followed as a natural result. At the same time, as the result of long-continued exercise upon open ground, a greater development of the muscles of the hip, thigh, and leg, namely, the glutei, psoæ, iliaci, and gastrocnemii muscles, would necessarily take place, until finally, through the influences of migration and the transmission of these new qualities to favored successors, a newer form of animal would be evolved, having a perfectly erect position, a straight flat foot, with five parallel toes.

His new food also exerted a powerful influence. The date and banana, which are produced by nature in such inexhaustible quantities, and which are so palatable and nutritious as articles of food, had much to do in changing the anatomical structure of the gorilla. These two fruits were abundant and easily obtained, and this easy accessibility had an influence in shortening the arm of the new upright gorilla-man. He could reach them with but little effort, as the rich banana grows on a low stalk, and the still richer date drops into his hand, and no longer needing to swing his heavy body among the trees by his arms in search of food, they shortened slowly by the simple but inexorable law of *disuse*. The powerful prognathous jaws hitherto so useful in tearing asunder the thick and toughened rinds of his former fruits, now gradually rounded and shortened through the atrophy of disuse, because his new food no longer required a strong muscular effort to fit it for his needs. Nature now did for him, without effort on his part, what he was formerly obliged to do for himself with slow and painful labor.

The northerly migration of the gorilla produced an effect strong enough to change the shape of his leg and foot, so he could walk in an upright position, through the development of the muscles of his hip and thigh. It shortened his arm and jaw, and rounded his skull. These changes were followed by another of immense importance—namely, that of increasing the size of his cerebral hemispheres by confronting him with an element of danger. When he found in the more northerly regions to which he migrated a greater supply of easily obtained and nutritious food, he also found himself face to face with new, dangerous, and destructive enemies who at once menaced his safety. These were the ferocious lion, panther, leopard, and python.

In undergoing the changes necessary to transmute the gorilla to the gorilla-man, and finally to a man, he lost some of his immense muscular strength and his former ferocity of disposition.

To compensate for these, and to secure his safety, he must use strategy and intelligent cunning to protect himself against his newly found enemies. He must invent weapons of defence, and this requires a development of inventive genius, and this again requires a development of the *cortex* or gray matter, which is the *thinking part* of the brain. In this way, under the stimulus of its new use, the brain of the gorilla during its transition period to a gorilla-man, underwent developmental changes, until finally, little by little, in the course of the ages, this organ became so highly specialized as to ultimately enable him to place himself at the head of the animal kingdom, and dominate over the world.

Perhaps future researches in the sequestered region of equatorial Africa may reveal to the patient laborer the fossil remains of these transition forms, or gorilla-men. But even if no such transition forms are ever discovered, the great laws of evolution will stand as solid truth. These early gorilla-men were necessarily savage and bestial, but both in form and intellect were considerably in advance of their simian progenitors. Their skins were intensely black, partly through transmission from the gorilla, of this special pigmented condition, and partly through the long-continued effects of a burning tropical sun whose caloric rays acted strongly upon the dark pigment matters of the skin. Their heads were probably covered with short woolly hair. The jaws were developed into a more rounded shape, but were still somewhat prominent, or *prognathous.*

There can scarcely be a doubt that the vast region of tropical Africa lying slightly northward of the equator was the favorable locality where the gorilla, after emerging from the dense forests bordering the equatorial line, underwent those structural changes that transmuted him into a pigmy-like man, or a gorilla-man, and finally to a black man.

These changes of form were induced by the influences above described, and acted for a long period of time. We can easily understand how in the first instance some bold, lusty gorilla wandered away from his ancestral forests, followed by a few who regarded him as a leader, and in more northerly regions found a new and more congenial habitat. Here, amid abundant and nutritious food, and a life on more open land, a change in the shape of some of his anatomical organs took place inevitably, and without any knowledge of such change on his part. When a gorilla found himself in the course of time with a straighter leg and a flatter foot, he naturally consorted with a gorilla having like qualities, and this resulted in a transmission of these qualities from parent to offspring. The gorilla was entirely unconscious of such changes that were taking place in him, but they did take place little by little until a new animal was finally formed.

According to this view, which seems to me to admit of no doubt whatever, the extensive and agreeable region of tropical Africa lying north of the equator was the only place where *man first appeared upon the earth.* After his evolution from a simian ancestor by the processes of anatomical change of structure above described, and in that special locality of tropical Africa, he henceforth underwent gradually other changes in his bodily structure. These changes at first were a greater development of brain substance, and a modification in the shape of the tongue to fit it for the function of articulate speech. We can easily imagine that the earliest forms of men had a very imperfect method of intercommunication. The tongue was long, thin, and flat to fit the prognathous jaws. As these rounded and shortened, the tongue also rounded and shortened, and became more muscular and flexible. This, with the development of the mobile lip on the rounded jaw, made intelligent speech gradually possible.

Of the ultimate development of speech and language we have nothing to do. Our task lies in studying the evolution of the organs of speech, which are principally a properly shaped tongue and rounded mobile lips. The development of these, and of the motor and sensitive nerves that supplied them, advanced simultaneously with the slow development of the brain.

As *ideas* arose in the brain, the tongue, acted upon by the nerves, expressed them, and the hands executed them.

When the evolution of man had advanced to a point where he could propagate his own species, and transmit to his successors his human qualities, the increase of this human animal, black and savage, but erect and intelligent, advanced rapidly.

He continued his northward migrations little by little. Experience and accident taught him much.

As he pushed his way towards the north by slow and perhaps painful stages, requiring ages to accomplish the journey, a time came at last when he reached the temperate regions bordering upon the Mediterranean Sea. Here a new and strange condition of things presented themselves. The cooler and more temperate climate slowly bleached his skin and straightened his hair. He found here the date in profusion, and cereal grains, both abundant and nutritious as food. The use of *fire* to cook the latter could not have been known to him until discovered by accident. We can easily see that in his domestic acts, or those of warfare against dangerous beasts, he might strike fire accidentally from a stone. Such a new and strange element would very naturally fill him with astonishment, and lead him to repeat the experiment. Once discovered, it became ever after a powerful ally to him.

We can understand how man in his slow migrations reached in time the valley of the Nile, and finding there a congenial climate, a well-watered and fertile soil, and the conditions of life favorable, he remained there for ages until his experience, acquired little by little, led him to found the early rude civilization of Egypt, and the also rude civilizations of Southwestern and Southern Asia, and the later and higher civilizations of Greece and of Rome. Such an advance from the lowest primitive savagery to the high civilization to which Egypt, Greece, and Rome attained, was necessarily very slow and painful. It required a vast lapse of time for the gorilla to emerge from his equatorial jungle, and undergo the anatomical changes necessary to transmute him, first to a transition form or gorilla-man, and finally to a man. This evolution of a man from an ape could never have taken place had the ape remained stationary in his native forests. Migration to other scenes, to different climates, and to new conditions of life were needed.

Having changed to a man through the influences brought to bear upon him by migration, it required another vast lapse of time before he could learn even the lower and ruder arts of clothing his nakedness, of cooking his food, and of constructing for himself a place of shelter.

We can well understand that an enormous period of time must have elapsed from the moment when the primitive black man first reached Northern Africa, rude, naked, and savage, with no speech except a few guttural sounds, with no arts except the art of using a rude and simple weapon to defend himself against wild beasts, and the accidentally discovered art of using fire, whose evolution and descent from his gorilla ancestor was then a matter of comparatively short ages before—down to the period when he had advanced sufficiently in his intellectual development to build the vast cities of Memphis, Thebes, and Luxor, and to lay the foundations of the mighty Pyramids, and thence onward in his career to the later age, when in the city of the Seven Hills he could don the imperial purple, and as master of the world give laws to mankind, and lead to distant conquests the well disciplined and invincible Roman legions.

The gap of time between a primitive black savage and a Commodus was indeed immense.

After these primitive men had reached the valley of the Nile, and made the earliest settlement of that fertile region, some of the bolder and more adventurous of these savages penetrated into the wilds of Europe and ultimately reached its most northern parts. Others invaded Asia, and in the course of ages founded China, India, Japan, and gave rise to the nomadic tribes and pastoral hordes that lived in the central and northern parts of that vast region.

It only required a sufficient length of time for those hordes of savage men to overrun the whole of that great country. As they slowly pushed their way northward, they reached in time the Asiatic border of Behring's Sea. They then crossed into North America over that narrow strip of ocean, and gradually overran our western border, going as far eastward as what is now known as Ohio. They then diverted their course and went to Mexico and Central America. Here they left numbers of men, who eventually founded those tribes that in later times became the shadowy cave dwellers, cliff dwellers, and mound builders. Still later they settled in Yucatan, Honduras, and other points in Central America, and founded those semi-civilizations whose ruins we now occasionally find, and whose magnitude and intricacy fill us with astonishment. Passing onward over the Isthmus of Darien, these migratory primitive men penetrated into South America, following the fertile western border of that continent. Here they ultimately founded a rude settlement, which afterwards became the empire of the Incas. Their extreme southerly migrations resulted during many ages in nothing higher than rude savagery and cannabalism.

This new animal, man, was restless, aggressive, migratory, and conquering. His large brain, his upright form, his mobile tongue, and his active and pliant arm, now trained to the use of tools and weapons, admirably fitted him to penetrate into the most distant regions of the earth and become final master over all other forms of animal life.

From Southern Asia his way was easy to the adjacent islands of the great Eastern Archipelago, and thence onward to the continental island of Australia. Deep intervening seas were no barrier to him, for his brain was adequate to the task of finding means to transport himself to those inviting islands that so thickly dot that pleasant sea, and which lay so near to his sight as to stimulate his curiosity and his desire to visit them.

The means to achieve new territorial conquests once acquired made these new conquests easy to his ambitious zeal.

The differences in the races of men are due almost solely to the effects of climate. If the primitive black man had remained in tropical Africa, he would always have been a black man. As he reached the temperate zones of North Africa and the neighboring countries, his skin bleached a little, and he became yellow. In Southern Asia his hue was still yellow. In Malaysia he darkened again, and this tint he preserved in northern tropical Australia. In India he assumed a red or copper hue, and this color was found in the savages that inhabited North America. In Mexico, Central and South America they darkened again. In Europe the skin gradually became white in the clear and cold air of those latitudes.

The men that permanently remained in Europe and ultimately lost the dark coloring matter of their skins, and became white, through the influences of climate, became in time the dominant race.

By their intelligent energy the higher problems of a refined and scientific civilization have been slowly worked out.

The difference between these higher and later civilized men and the primitive men is immense, and the difference again between the primitive man and his anthropoid ancestor is just as great. We need not look for intermediate or transition forms. The evolution of man from his simian progenitor was extremely slow and gradual.

As man stands at the head of the long line of animal forms that have successively appeared upon the earth, is he to remain there, or will there arise some time in the remote future a newer and more advanced type of life as the product of the law of evolution?

Is this great law, by whose orderly operation all forms of life, from the little protoplasmic cell of the Silurian age to Quaternary man, have been slowly evolved, still in operation?

Are animal forms still slowly changing to new and higher forms? Are new animals coming upon the earth?

The answer can be safely given as No. The processes of evolution require for their operation certain favorable conditions of the earth, such as were present in the ages prior to the late Tertiary period and the Glacial epoch. From the Silurian age to that time in the Tertiary age when the great mountain ranges were uplifted, the surface of the earth was admirably fitted for the various forms of life as they successively appeared. In the Silurian era the quiet seas and the warm and partially obscured air were well adapted for the evolution and development of vast numbers of protozoan and molluscan forms of life. The Devonian seas, warm, quiet, and abounding with myriads of protozoans, gave a congenial home to the great fishes that appeared in that age.

The Carboniferous period, with its vast forests, made reptile life first possible, and in the succeeding Triassic, Jurassic, and Cretaceous periods these great animal organisms found the conditions of life so favorable that they developed rapidly into newer, more divergent, and more highly specialized forms.

At this period in its history the earth had so far progressed in its geological development as to offer rich and extensive pasturages to great numbers of mammals that appeared in the Eocene, the Miocene, and the Pliocene divisions of the great Tertiary period. During the slow and regular progress of these immensely long periods of time, the earth was a rich and almost boundless natural storehouse, where food was abundant and easily obtained, and the air warm and clear, and the conditions of life easy. Everything was favorable to the evolution and development of varied and exuberant forms of life; and they appeared accordingly. The Glacial period, following the upheaval of the great mountain systems, served as a partial check to the processes of evolution. When man emerged from his simian ancestors, there was only a restricted zone of the earth where his evolution was possible, and when he increased in such numbers as to overrun the earth, his destructive tendencies put an effectual stop to any further evolution of life.

In later ages, when conquest and commerce led him to visit distant places, and when his sharp and practical civilization extended itself, all forms of life that were dangerous to his safety, or that could not subserve his needs, were destroyed, as useless encumbrances. These destructive tendencies are still in active operation. As man brings under his civilizing hand more and more of the earth's surface, all animal life that is not useful to him will disappear, partly from the instinctive and natural dread that animals feel in the presence of man, and partly through the relentless warfare waged upon them by man for their extermination.

A familiar example of this destruction of animal life has been witnessed in our own country. Formerly North America was the home of the copper-hued Indian, the bison, elk, deer, wolf, fox, beaver, and many other lesser forms. When the white man came here and introduced industrial arts, and began to till the soil, a warfare at once sprang into activity. Civilization extended itself in many ways. The railway was the prime civilizer, and before its influence all wild and useless animal life found here was rapidly and necessarily destroyed. Vain and sporadic efforts have been made to stop this destruction. But its continuance is inevitable and inexorable until all forms of life not useful to man are totally exterminated.

Savage men and savage beasts are an obstacle to the progress of industry and refinement, and before the steady advance of these higher influences the savage and useless element must give way.

The march of human progress is steadily and ever onward. No attempt to stop it can be permanently successful. An endeavor to preserve a useless race of any form of animal life, whether from sentiment or from a hope of its ultimate use to mankind, will result in complete failure.

The evolution of man marked a new era in the geological history of the earth. His special anatomical structure fitted him to compel to his use the lower members of the animal kingdom of which he is a part.

While the earth supported in former ages millions of animals, man numbers at the present time many hundreds of millions, and the capacity of the earth to support these has hardly yet been touched.

Only one fourth part of the earth's surface is land, the remaining three fourths is ocean. Of the land area, a large part is occupied by mountain ranges, by arid tracts, or covered by perpetual snow, and is thus useless to man. The extent of land which is useful to him, either as a habitat or for tillage purposes, is comparatively small. Yet limited as its area is, it is still sufficient to support a population many times greater than it now is.

Only a small part of Asia is occupied by man. Africa is practically uninhabited except a restricted area along its northern border. The vast islands of Malaysia are only occupied by a handful of men.

South America stretches away in fertile solitude, except here and there a small spot of settlement. North America can add to her seventy millions more than ten times that number, and support them all abundantly.

Many ages must elapse before the resources of the earth are exhausted. Vast areas of land in Asia, Africa, North and South America are arid, and at present useless. As populations increase and extend themselves more and more over the earth, these arid regions will be brought under cultivation by means of irrigation, and transformed from a desert to a garden capable of sustaining many millions of men.

As science, art, and education are more generally extended and understood, the condition of men will be improved, and greater ease and happiness will be the result. In early ages, when ignorance was dense, and the arts were of a rude and simple character, the conditions of life were much harder. As men migrated to the colder and more inhospitable regions of the earth, their lack of knowledge and want of experience militated severely against them, and they accordingly suffered from privations, disease, and the want of proper care. The evolution of intellect revolutionized slowly and steadily the condition of mankind. In modern times three discoveries have enormously advanced the welfare and the comfort of the world, and made the present century the most highly advanced of any since the appearance of man upon the earth. These are the discovery of the forces of steam, of electricity, and of chloroform. By the aid of the first the heavy work of the world is done, and transportation to distant places is accomplished with celerity and comfort.

While the steam-engine is patiently and untiringly doing the drudgery of the world mankind is improving its condition and moving to a higher plane of civilization and refinement.

Electricity that has done so much for our comfort and enlightenment is only in its infancy. We cannot yet tell what that subtle force has in store for us in the future—that *force* that so closely resembles that other *force* we call *life*. While steam and electricity are of such incalculable value to us, the third force—chloroform—takes an equal rank. Both the body and mind of man are quickly conquered by pain, whether this results from accident or disease. The processes of intellect and muscular activity must cease when the body suffers pain. The mighty power of steam and the wonderful forces of electricity must lie dormant and useless if the brain and the hand of man are paralyzed with pain. Under the benign influence of this wondrous drug pain ceases and the surgeon's knife is robbed of its terrors. A little of its subtle vapor lulls the sufferer into a quiet sleep from which he awakes free from the trouble that agonized his body and menaced his life. It is the triumphal master over many forms of disease. These three forces have done more than all others to benefit mankind. Their discovery was a veritable triumph of human intellect.

The exuberance and over-populousness of animal life on the earth has been regulated and held in check by the operation of several influences. The lower organisms that have been so prolific in their reproduction have been preyed upon by the higher orders of animals who used them as food. Every species of animal has found a destructive enemy in some other species of animal, and this process of one animal preying upon another has served in all ages as an effectual check upon the over-production of any one species.

When man, after his evolution, became the dominant animal there was no other or higher animal to hold in check the rate of his increase. If his reproduction was to be regulated and repressed when it became too exuberant some different influences from those that operated upon the lower animal world must be brought into activity. Such influences were quickly set in operation. They were three in number:

First. His internal destructive warfare.

Second. The ravages of disease.

Third. His own individual vices.

As man migrated to distant places and settled there, and in time received the local impress of climate and of special habits and modes of life, he diverged in his superficial characters and became a tribe or community by himself, with his own local ideas, interests, prejudices, and ignorances. He learned to regard himself with complacency and his neighbor with hostility and contempt.

If he saw his neighbor's condition better than his own his cupidity and covetous nature was aroused, and he sought to possess himself by force of what was not his own. This at once led to warfare, and a destruction of life followed.

These early tribal quarrels, incited by local petty jealousies, where the rights of others were little understood and less cared for, had the effect of keeping in check the progress of these primitive men. In later ages, when tradition began to be followed by cloudy history, the destruction of the human race was still further carried on by the influences of sectarian zeal, by piracy, by conquest and pillage, and by civil war.

These influences were so potent and so destructive that their effects have been seen several times in a visible diminution of the human race.

The ravages of disease have also acted as a powerful check upon the increase of mankind. As people aggregated into communities and nations and lived in close contiguity they were often ignorant or unmindful of sanitary laws, and in consequence they suffered severely from sporadic or epidemic disease. It may be stated generally that disease is the result of some poisonous principle introduced into the human body from some surrounding source, and that when once introduced it causes a degeneration and destruction of vital tissues. These necrotic influences are *now* well understood and can be combated with great success by the administration of proper drugs. But in the earlier ages, now under consideration, the art of medicine was imperfectly understood, and disease once established made fearful and destructive ravages.

The vices of men have had a certain economic value.

It is now well understood, and was as true in the earliest ages as now, that the vices of men were the result in a greater or less degree of a peculiar condition of disease. Men who are habitual criminals, or who are cruel and vicious, or who have an ungovernable craving for intoxicants, are generally the victims of cerebral disease, and lack the mental balance necessary to make them sound and responsible beings. It is from the ranks of these classes that the *insane* are largely recruited. When criminals prey ruthlessly upon society human laws operate to check them, and they are confined or executed, and thus removed from doing further harm.

If they allow unrestrained action to their vicious or intemperate habits, the asylum or the grave ends their career.

So in this way the vices of men, when freely indulged in, act as a check upon them by shortening or ending their lives.

The three influences, then, of war, of disease, and of vice, act as powerful checks upon the too rapid increase of the human animal.

These influences have in past ages acted with such baleful and malignant force, as on several occasions to seriously affect the welfare of mankind.

Thus in the reign of the Roman Emperor Justinian, A.D. 527–565, the combined influences of war, famine, and pestilence caused a destruction of nearly one hundred millions of human lives, and depopulated some of the fairest provinces of the earth.

The enlightenment of modern times, and the universal spread of education and of science, will put a stop to these terrible conditions that so grievously oppress the world, and men will live longer and better and far happier, when wars cease, when disease is controlled by the wise physician, and when vice is made less attractive by placing within reach of the vicious a better and easier condition of life.

When *selection* exerts its influences upon men, and they are made wiser, better, and healthier thereby, the earth in her broad and ample domain will comfortably cradle many millions of her children that now perish through ignorance and its attendant evils.

It is not probable that man will undergo any anatomical changes of form in the future. He has undoubtedly reached the highest point possible in his *structural* development. The more favorable conditions of life he will enjoy through the influences of scientific advancement will give him more perfect health, and an immunity from many severe and dangerous diseases that now afflict him. He will live longer, and better, and die finally of purely *senile* changes in his anatomy and his physiological functions.

But that any new or different animal form will ever appear is so improbable that we are safe in pronouncing it impossible.

No such structural change could take place except after the lapse of an immense period of time, and as man is now constituted, he would regard any change of form as a monstrosity, and destroy it as useless.

We can safely assert, however, that the processes of evolution have ceased, and that no new animal form will ever appear upon the earth.

In this practical modern age, when everything is valued according to its real use to man, either to increase his gains, his power, his health, or his comforts, nothing will be spared, or allowed a place in life, that cannot minister to his wants.

Only such animal forms as he can use to increase his profits, his pleasure, or his vanity, will be permitted to exist. All others will be gradually destroyed, as useless to his needs, or dangerous to his safety.

The time is not far distant when no animal will be found outside a menagerie, who cannot be utilized either by the yoke or the spit.

Every one beside must give way ultimately to the civilizing influences man is slowly but surely extending over every province of the earth.

When we see the great number of fossil remains of animal forms that have come down to us from remote past ages, and study also the myriad living forms about us, from the gigantic elephant down the long line of life until we reach those invisible organisms that swarm everywhere about us, we look upon some of them as mere freaks of development, and think that the law of the evolution of life has run riot in the profusion of forms we meet.

Viewed in the light of our practical modern times, many of these forms seem utterly useless, and, as far as we are able to discover, they serve no possible purpose in life. And it is no doubt true that they are useless, and they certainly are often loathsome and dangerous. Their existence can be explained only on the ground of the intense activity of vital processes and the rapid development of varying forms of life under the extremely favoring circumstances of abundant food, agreeable environment, pleasant climatic conditions, and an ability to protect themselves from destructive influences.

Nature is always profuse. She produces many where few are needed. She was so in those far distant past ages in the production of myriads of animal forms, both of divergent and of closely parallel types, and she is so to-day in the production of many of the lower and minute forms of life.

The inferior organisms are usually enormously prolific—thus, many protozoans, or systemless animals, some fishes, insects, and those repulsive organisms grouped under the name of vermin, yield vast numbers of eggs—sometimes many millions—of which the greater number are lost, either before, or immediately after, incubation. Out of the number that escape destruction enough reach maturity to continue the species upon the earth.

In speaking of the vast lapses of time necessary in the course of evolution to change one animal form into a newer and more highly developed form, it must be understood that this means not centuries nor thousands of years, but *millions.* No visible change of form can take place in animals, except by artificial breeding, in any period of human history.

It requires a much greater length of time to produce even a slight anatomical change. The various geological divisions of time are to be reckoned as each of millions of years' duration. The Azoic age must have required many millions of years before the earth was cooled down to an encrusted condition to fit it for the formation of a quiet universal ocean. The Silurian age must also have been of vast length to develop so many forms of early and of crustacean life.

The Devonian age with its evolution of fishes, the Carboniferous age with its formation of the coal measures, the Cretaceous age with its development of reptilian life, the change of these into mammalian life in the Eocene, Miocene, and Pliocene ages required a prodigious number of years to accomplish such important changes. The evolution of the great apes in the Quaternary age, and the transmutation of these forms into man, and his slow progress from his primitive state to even an early stage of his rudest civilization, required, we may safely say, millions of years more.

So that, in speaking of the time required for the geological changes that have taken place in the condition of the earth itself, and the contemporaneous changes that have taken place in the animal kingdom, from the primal protoplasmic cell up to man, we must compute it as many *millions of years.*

An approximate estimate has placed it as not less than forty millions of years. Whether this represents anything like a correct estimate we do not know. It is, however, certain that the time has been of enormous duration.

CHAPTER XVII.

TERRESTRIAL AND COSMOGENIC PROGNOSIS.

The formation of the earth—Appearance of life—Evolution of man—His power—His use of fire, water, electricity, drugs—Prognosis of the earth—Loss of oxygen—Cessation of animal life—Cessation of plant life—Radiation of heat into space—Loss of heat by our sun—Its effect upon animals and plants—Ultimate loss of all heat—Motions of stars—Motions of Arcturus—His collision with our sun; its effects—Coalition of all the suns in space—Formation of a vast central mass—Its explosion and the formation of a new universe—Development of life on a new earth—Repetition of the process.

WE have now traced, step by step, the history of the earth in its many geological changes, from the long remote past when it was a part of the great central glowing mass of fiery vapor from which all the bodies in the universe were formed, down to the present time, when our eyes behold its sunny fields and smiling landscapes.

We have seen that it was first thrown off from the vast central mass by a great chemical explosion, and again thrown off from the mass that now forms the sun of our own solar system. We have followed it as it slowly cooled in its circling orbit around the sun, first from a mass of fiery vapor, until it became a molten mass of a pasty consistency, when it took upon itself its present spheroidal form. We have watched its slow encrustation in the cold of space, and have seen the electrical phenomenon of the formation of water by the chemical union of oxygen and hydrogen, which after many ages became a warm, fresh, universal ocean.

Later in its career we saw a slight upward movement of the submerged crust, and soon after, the long, low, bow-shaped range of the Laurentian Hills reared their heads above this universal sea.

A long period of quiet rest followed this uplift of dry land, during which time the air and the sea were warm and quiescent. In this period of repose, when the still waters bathed those silent coasts, and not a breath ruffled the surface of the sea, a subtle chemical process was taking place in the waters of those little shallow inlets of the solitary shore. The elements of the water were combining under the influence of a peculiar power we call chemical energy, and from this combination there results a little globule or mass of a jelly-like substance we call protoplasm. This little mass or cell of protoplasm soon developed a special adaptability to do a special thing, and this peculiar power to do these special things we call life.

This subtle vital phenomenon once established, it developed a power to go on in an ever advancing scale, evolving the different forms of life in successive and regular order, from the little protozoan composed of a single cell to that highly specialized organism we call man.

We have seen that man, although he sprang from an ape—the gorilla—and had his origin in the vast regions of Africa lying a little to the north of the immense equatorial forests, has, by virtue of his *brain*, been finally able to overrun, and dominate, and civilize the earth.

He has compelled to his use the forces of fire, of water, of electricity, and the remedial powers of drugs, and by the aid of these, the whole earth, with her varying zones of *heat* and *cold* lie open to his hand.

If we cast a retrospective glance backward along the line of those vanished millions of ages to the time when our earth was only a mass of fiery vapor, we can see with our mental vision all the many and varied changes that have taken place in the geological evolution of the earth itself, and in the evolution of the myriads of forms of animal life, as well as the myriads of forms of plant life.

All these changes pass before our minds like a mighty panorama, unfolding itself little by little, but in a regular, orderly, and sequential manner until the picture of to-day, with grand and beautiful nature everywhere about us, and all the sciences, arts, and refinements of centuries open to our view.

As we look upon the glorious earth with all its beauty and loveliness, with all its comforts and happiness, and, alas, its sorrows, too, and its miseries, we ask what is to be the end of all this, what is the prognosis of the earth ?

To answer this question I have coined the phrase, which is the title of this chapter, Terrestrial and Cosmogenic Prognosis.

Prognosis may be defined as the judgment formed by the reasoner regarding the future progress and termination of the subject or thing upon which he reasons.

This judgment is based upon facts that have previously occurred, that are occurring constantly about us, and that probably will continue to occur in the future.

Reasoning in this way we can determine with great accuracy and precision the prognosis of a disease, of a nation, of a planet, or of a universe.

We naturally inquire, then, what is the prognosis of the earth upon which we live? Is it to go on indefinitely in its present condition as the abode of animal and plant life, or will there come a time ultimately when all forms of life will cease as a result of terrestrial changes that will make life impossible?

From what we now know of the changes that are slowly taking place, the latter view is the probable one.

Our earth circles about the sun at such a distance that the supply of light and heat received from him is extremely favorable to the continuance of animal and plant life. This supply of light and heat is stored and preserved by the envelope of atmospheric air surrounding us. Were it not for this envelope of air, the direct rays of the sun would blind and scorch us by day, and at night we should be plunged in destructive cold by the radiation and dissipation of the heat into space.

We have reason to believe that such a change, although upon a much smaller scale, has taken place in our satellite, the moon, which now circles about our earth an opaque mass of insensate stone.

Science teaches us that changes are slowly taking place in the condition of the envelope of the atmosphere surrounding our earth. These changes consist in a gradual attenuation of the air through a loss of one of its constituents—oxygen. If this is true, and there seems to be abundant evidence to sustain the view, a time must inevitably come in the far distant future, when this attenuation will reach such a point as to make the air inadequate to carry on the process of animal respiration through its loss simply of oxygen gas. When this point is reached, animal life must cease altogether.

Plant life may continue, however, for a considerable time after animal life has passed away, and until the time arrives when the attenuation of the air has reached such a point that it cannot hold a sufficient quantity of carbonic acid gas to sustain it, then plant life must cease also. As this attenuation of the atmosphere goes on, the ocean will be slowly dissipated until it no longer exists, and in the still later future the earth will reach the condition in which our moon now is—a mass of dry barren rock without any vestige of life upon it.

These changes in the condition of the air and the earth must necessarily be very slow and gradual, and cannot be felt until long after the time when man has subdued all the land area of the earth to his uses, and has himself become extinct.

Terrestrial changes of this nature require such great periods of time for their accomplishment that ages must roll away before this end can be reached.

It is a well determined fact that the heat of all the luminous bodies in the universe is being slowly radiated into the abysses of space. It follows, therefore, that a time must come in the future flight of the ages when all these vast stores of heat will be lost in the darkness and cold of space, through which the luminous bodies are now moving. This loss of heat has occurred in the case of our own earth, which now has no sensible heat of its own. It is no doubt true that the planets of our system that lie beyond us—namely, Jupiter, Saturn, Uranus, and Neptune—have also parted with their heat, and now pursue their orbital way around the sun as cold, lifeless masses of barren rock.

Astronomers tell us the sun is slowly parting with his stores of heat, and that this great timepiece is gradually losing time. This is what we should expect, for a heated body moving in the intense cold of space would necessarily lose its heat in the course of time and become cold, no matter how great its quantity of heat might be.

If our sun lost only a few degrees of heat it would at once destroy all forms of life upon the earth.

He need not grow completely cold nor lose all his heat. If he lost only enough to lower the mean temperature of the earth a few degrees, it would be fatal to the continuance of any form of life. A very slight change in the supply of heat received from the sun would be sufficient to produce prodigious results, and these results would be the almost immediate disappearance of life.

This loss of heat by our sun is what is actually taking place at the present moment, by radiation into space. The amount of heat stored in the sun is so great, however, that a long time must elapse before he can lose enough to be fatal to life on the earth. But that time will ultimately arrive.

This gradual loss of heat is true not only of our sun, but of all the suns that compose our sidereal system. Each sun pursues its path in space, and bears a certain relative position to the other suns, but they all are slowly but surely parting with their stores of heat. As this heat is lost in the frigid depths of space, and can never be recovered, no one of the suns can regain any part of the heat lost by any other sun. They must, therefore, continue indefinitely to part with their heat until all the suns with their attendant planetary systems shall become dark masses of rock, moving silently in cold and darkness.

What then will follow?

Will these millions of glorious suns that now shine with such splendor, and stud the vault of heaven with jewels of brilliant light, after they have lost their heat, pursue their solitary way forever in cold, never-ending night? We think not. What, then, will be their final end?

We know by actual measurements that some stars are approaching our sun, that some are apparently receding from us, and that many seem to have a general parallel direction of motion towards the constellation of Hercules.

Thus, the star Arcturus, according to the late observations with the great telescope at the Lick Observatory, is approaching our sun at the rate of four miles per second, and that many of the stars are moving towards us at varying rates of speed from four to twenty miles per second.

Suppose Arcturus continues to approach us at this same rate of speed, or even still more slowly, a time must come in the future when he will reach us. This is not at all improbable, for if his motion is towards us at a given rate of speed, there is nothing in frictionless space to check his motion, except his gradual radiation of heat, as he continues his flight towards our sun. This loss of heat may retard his motion to one mile a second, or even less. It may fall as low as one mile per minute. We cannot tell. But however slowly he may move, a time must finally come which will bring him into collision with our sun.

What, then, will happen. We must reason from known physical laws. When two bodies come violently into collision, *heat* is at once generated, and the greater the colliding bodies are, the more violent the impact, and the greater the amount of heat generated. Now if two such vast bodies as the great sun Arcturus and our own sun should violently come into collision in space, if each had lost a part, or all of his heat, the tremendous impact would cause such a generation of heat as to volatilize both bodies, with all their attendant planets.

If this collision should occur by Arcturus *meeting* our sun, the collision would have another effect, namely, that of *annihilating* the motion of both bodies. But if the collision should occur by Arcturus *overtaking* our sun, the motion of both bodies in space would be accelerated. In either case a great disturbance would be the result. If the motion was lost, and the great combined mass of volatilized fiery vapor of both suns stood still, it would find itself in the pathway of other suns in motion, and other collisions would inevitably occur. But if, on the other hand, the motion of the new body was increased by the impact, its direction of motion would be so disturbed as to cause it to crash into other suns in its pathway.

The inevitable consequence of so profound a disturbance of the heavenly bodies would be gradually felt throughout the universe. The increased mass of the two combined bodies—Arcturus and our sun—would be sufficient to cause it to attract to itself other suns by the force of the increased power of gravitation, and any other sun thus attracted would be instantly volatilized and augment still further by its own mass the mass of the original body. This would again increase his power of attraction, which would be still more widely felt, and more distant suns would be attracted to this vast body and become fused with it, and thus, by increasing its mass by every new addition of a sun, its power of attraction would be enormously increased also.

By the gradual but continual attraction of this great and ever-increasing mass of fiery vapor the most distant suns, whose feeble light glimmers on the remotest outposts of our universe, and all the nebulæ, and all the masses of star-dust everywhere, would be forced by the enormous attractive power of this immense and newly formed body to coalesce with it and become a part of it, until a time finally arrives in the distant future when there will be but one vast mass of fiery vapor, formed by the forced union of all the millions of suns that now shine in our skies with such beautiful light, and seem so secure and so permanent.

This ultimate coalescence of all the suns in the universe is the only end that can be logically reached, if any two suns collide in space, whether they be Arcturus and our own sun, or any other two of the heavenly bodies.

We know that Arcturus *is* directly approaching us, and we know of no power to divert his course from our sun. He must, therefore, in the course of time, reach us.

Perhaps other suns are moving towards a sun that lies in their pathway, and that distant collisions between two such bodies may occur.

Our great equatorial on Mount Hamilton may reveal to us that such is the case, and that suns in remote parts of the universe will ultimately crash together.

In either case, however, whether the collision occur betwen Arcturus and our sun, or between any two distant suns, or between several pairs of suns, either simultaneously or successively, the result finally will be the same—that is, one of the bodies will have a power of attraction so immensely great that he will be able to attract to himself all the other bodies in the universe, and by such a union form a single one.

Such a body of fiery vapor formed by the fusion of the many millions of suns in our sidereal system would be too vast in size to express in any known terms of measurement. Yet the human brain can readily and easily comprehend and appreciate it.

Our mental vision can construct, as it were, a point of observation somewhere in space where we can watch through the immense flight of the ages this mighty agglomeration of suns, and take note of its future operations as they are unfolded to our view. What is the probable future course of this great body of incandescent gas, formed out of every sun in the universe?

It will undoubtedly repeat what it did before. Its terrific commotion will again cause intense chemical activities among its elementary particles, and the generation of these chemical activities will give rise to a chemical force sufficiently powerful to cause an explosion which will rend the enormous mass asunder and cause its vast fragments to once more fly off into space.

The force of such an explosion must of necessity impart to each fragment a rotary motion, and this movement of rotation would cause each fragment to throw off successive peripheral particles. In this way each fragment would become a sun, and its particles a scheme of worlds circling about it, at varying distances from it, but all held to it by the power of attraction.

The same process of cooling and encrusting of the attendant particles would again occur, until they finally became planets. Those most favorably situated as to a supply of light and heat from its parent sun would become a fitting abode for the evolution of another course of life, and the same process would again take place of the changing of animal forms from the lower to the higher types.

Life would undoubtedly appear again upon a new earth, as it did in our Silurian age, and in the same way by the *chemical union* of six primary elements under favoring circumstances. If the new earth was situated at the same distance from the sun as our earth is, the same processes of development of life would go on again as they have occurred in past ages in our own history.

The same natural laws would be in operation, and they would produce similar results. It is not impossible nor improbable that such a process of geological and physiological development has followed the formation of a *previous* sidereal system, and having gone on in the same or in a similar way as it is now going on, and reached its highest point of development, ultimately terminated by the coalescence of all the suns in space.

There is no scientific reason why this should not be true, and there is no reason why this same process of development should not occur again in the future.

If it can occur again, it can occur many times and indefinitely. So far as we can reason there is no limit to space, nor time, nor to the durability of matter. As there is ample space, and limitless time, and durable matter, the process of forming a new universe of suns, and new systems of attendant planets, and new developments of life, can go on time after time until something arises to prevent it. Nothing can arise, so far as we can reason, to prevent the formation of new systems of suns, except the gradual loss of matter in space by the successive explosions of the great central mass. If at each explosion a portion of the heated matter should be projected so far into space as to be beyond the influence of the bodies composing the new universe, it might be forever lost in the depths of space. If this loss of matter should occur a sufficient number of times, a point would ultimately be reached when the remaining mass of matter would be insufficient to form a system of suns of a size great enough to give a supply of light and heat to their attendant planets that would stimulate into activity the chemical energy we call life.

In this view the loss of successive portions of matter would go on until the whole system of suns was dissipated in space as isolated fragments of inert matter having no relation to other masses.

The law of attraction in force among the bodies composing the universe is sufficiently powerful, however, to prevent the loss of matter going on to any considerable extent. And it is probable that such a loss would be relatively so small that it would be of no practical value in the future operation of the evolution of worlds.

We can see, then, that a universe of suns can arise, that systems of planets can circle about them, and that the most favored ones can give rise to the various phenomena of life. Animals and plants will spring into existence and follow the law of evolution from the simplest to the most complex forms until the highest form is reached—which we call man.

After an interval of time of long duration natural causes will compel the whole universe to coalesce and become one body. This, under the stimulus of chemical law, will separate and form a new universe of suns with their attending planets, which will again pass through the same phases and the same changes that *our* universe has passed through and that our earth has passed through.

Then another evolution of life will follow, and new animals and new plants will arise and pursue the same path of development that ours have done. They will flourish for a time in a world as bright and beautiful as ours, and after reaching their highest point of development, slowly decay and finally return to their original elements.

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